Results of Auger Analysis of ATLAS Pixel Chip Wire-bond Pads

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Three assemblies analyzed:

- Single die direct from wafer
- Single die after bump deposition
- Single chip MCM-D assembly after flipping
- Full module would not fit into machine vacuum chamber

Analysis performed by Charles Evans & Associates, Sunnyvale, CA

Analysis Performed

Basic Auger analysis:

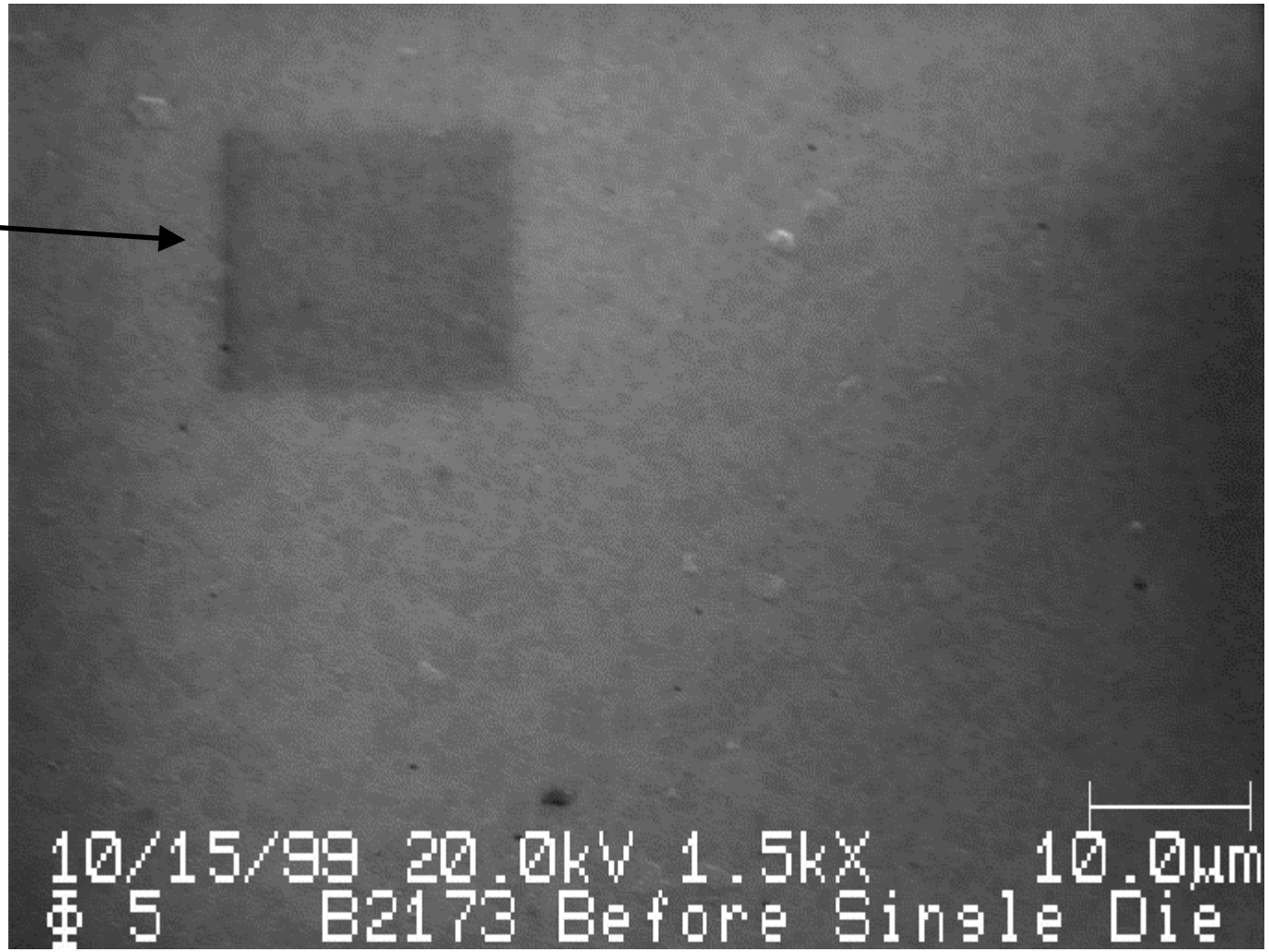
- Bombards pad with 20 KeV electron beam and analyzes Auger electrons emitted. Analysis of spectrum provides element analysis, and some information about whether it is elemental or not. Beam size is sub-micron, and it is rastered over selected region for analysis ("area" analysis).
- Low energy Auger electrons have only few nm range, so perform Ar sputter (4KeV beam 3mm in diameter) to remove material, then re-do Auger scan. This cycle is typically repeated 10-20 times, tracking particular elements identified in initial full spectrum. Full spectrum also taken at end of analysis.
- Disadvantage: depth calibration comes only from correlation with expected sputter rate. SiO2 assumed (140A per min), other materials have different rates, and cross-linked organics can be much slower to sputter off.

FIB Section with subsequent Auger analysis:

- In order to gain additional information on contamination, a small vertical slice was made using FIB to expose a vertical section of the bond pad region for more complete analysis. Then Auger "line" analysis instead of "area" analysis done.

Single Die Direct from Wafer

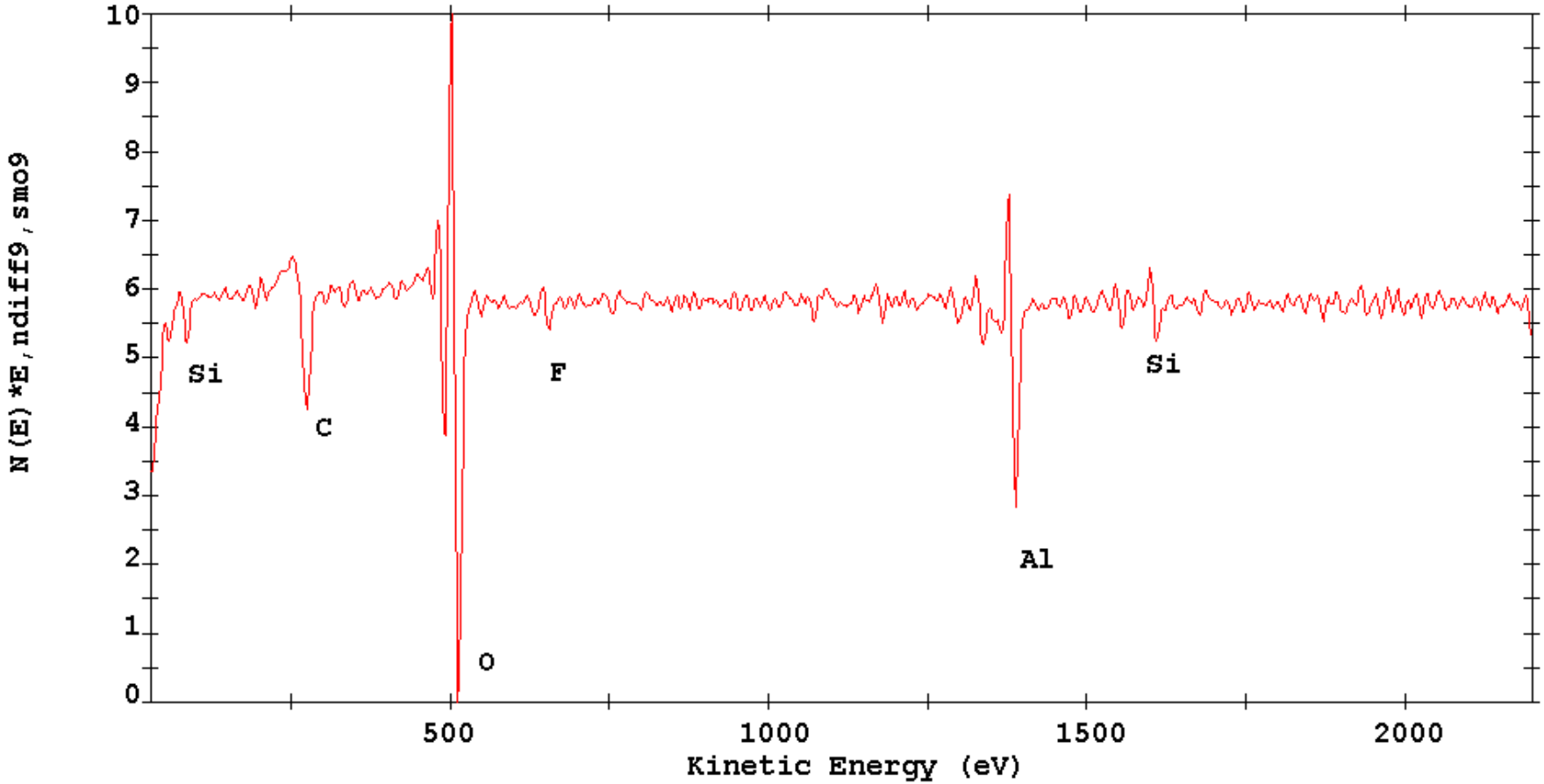
Region used in Auger analysis. Image recorded after analysis was performed.



AES Survey PC 15 Oct 99 Area: 1 Acq Time: 3.62 min

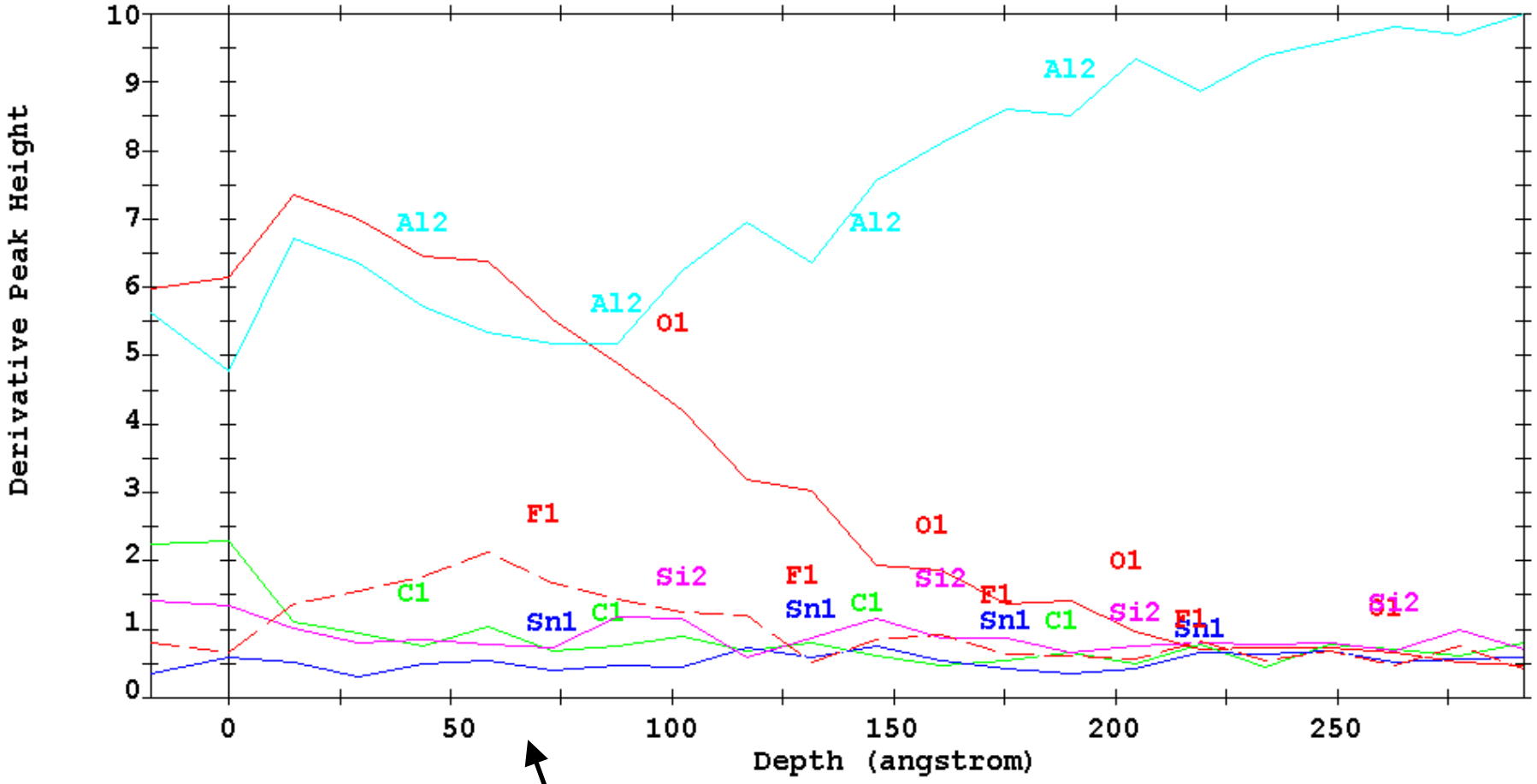
File: b2173006 Before single die As received

Scale: 108.895 kc/s Offset: -621.320 kc/s Ep: 20.00 kV Ip: 1.251e-08A

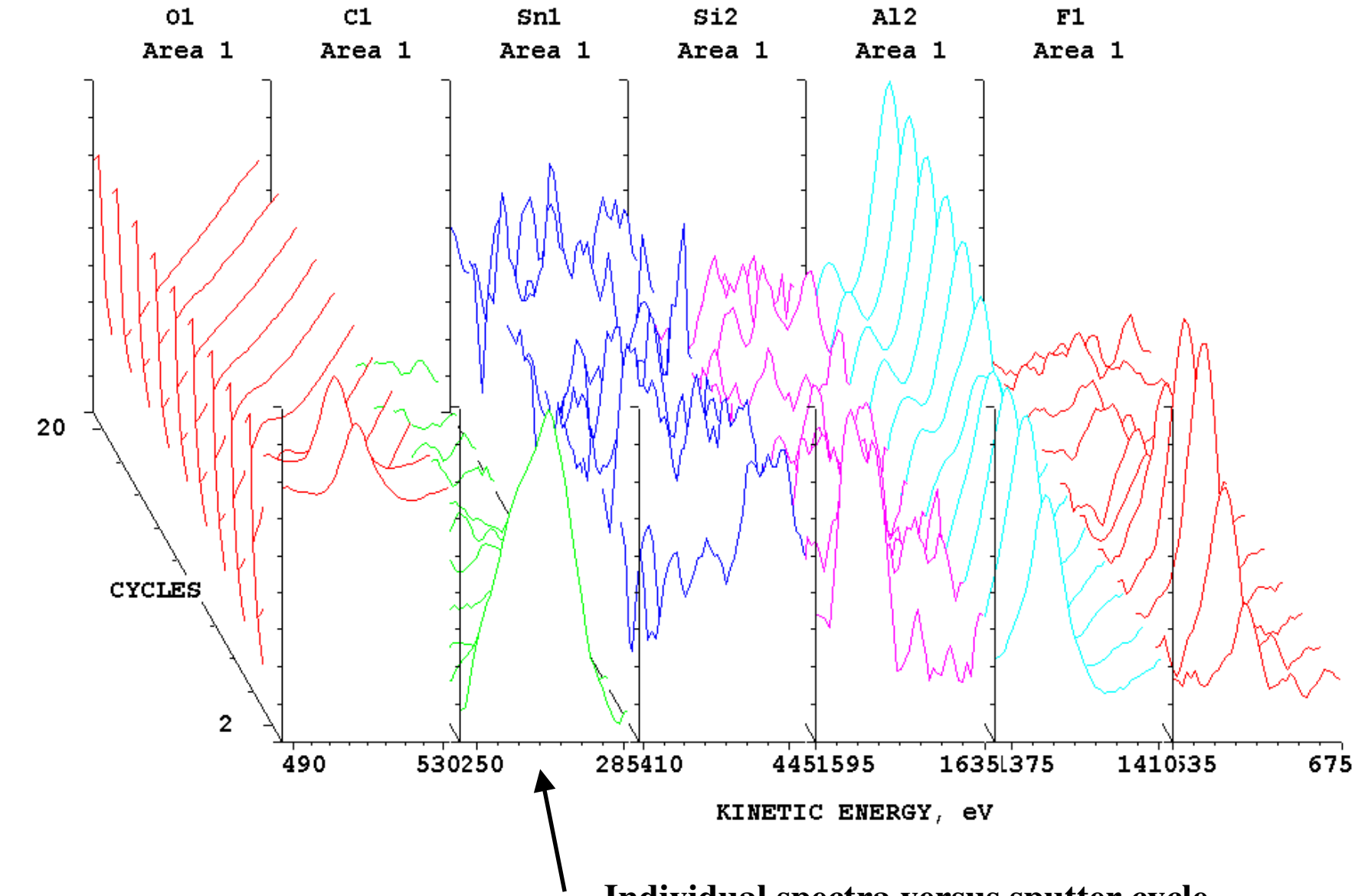


Initial full survey, used to define spectra windows to track during depth profiling.

AES Profile PC 15 Oct 99 Region: 6(F1) Area: 1 Sput Time: 2.00 min
File: b2173007 Before single die As received
Scale: 281.460 kc/s Offset: 0.000 kc/s Ep: 20.00 kV Ip: 1.251e-08A

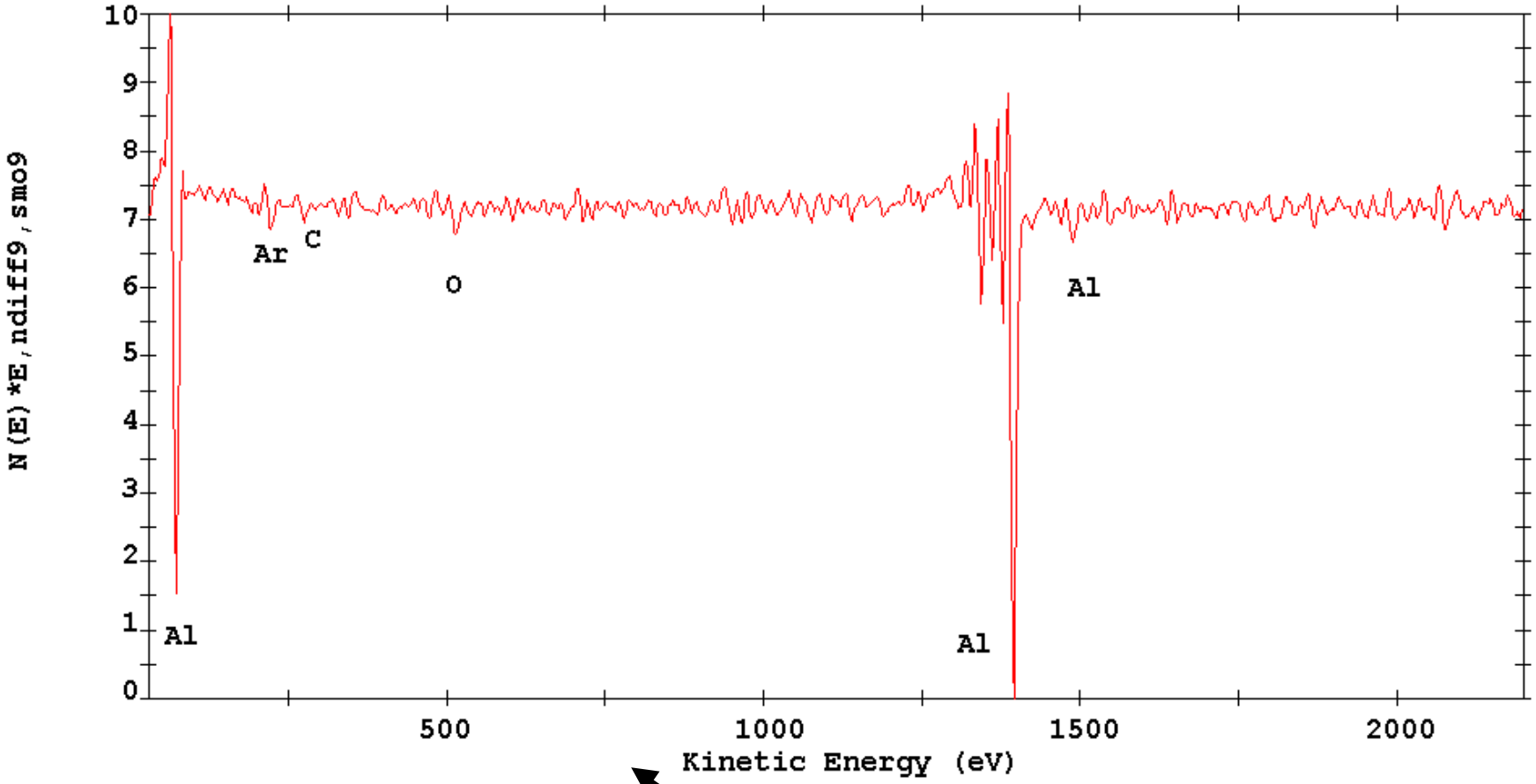


Depth profile of previous peaks, normalized using SiO2 sputter rate, raw data (not corrected for sensitivity).



Individual spectra versus sputter cycle

AES Survey PC 15 Oct 99 Area: 1 Acq Time: 3.62 min
File: b2173008 Before single die After profile
Scale: 86.107 kc/s Offset: -607.245 kc/s Ep: 20.00 kV Ip: 1.251e-08A

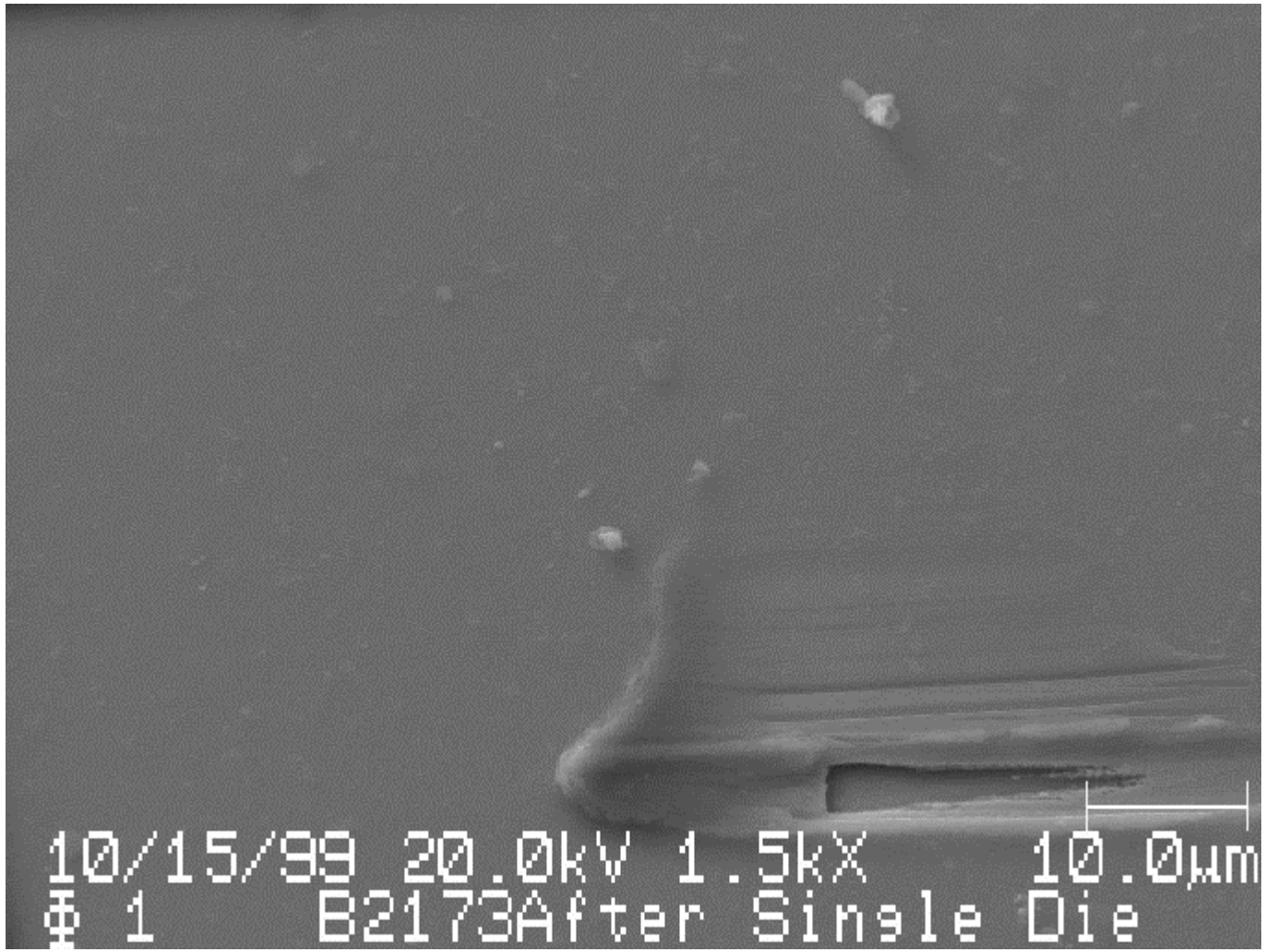


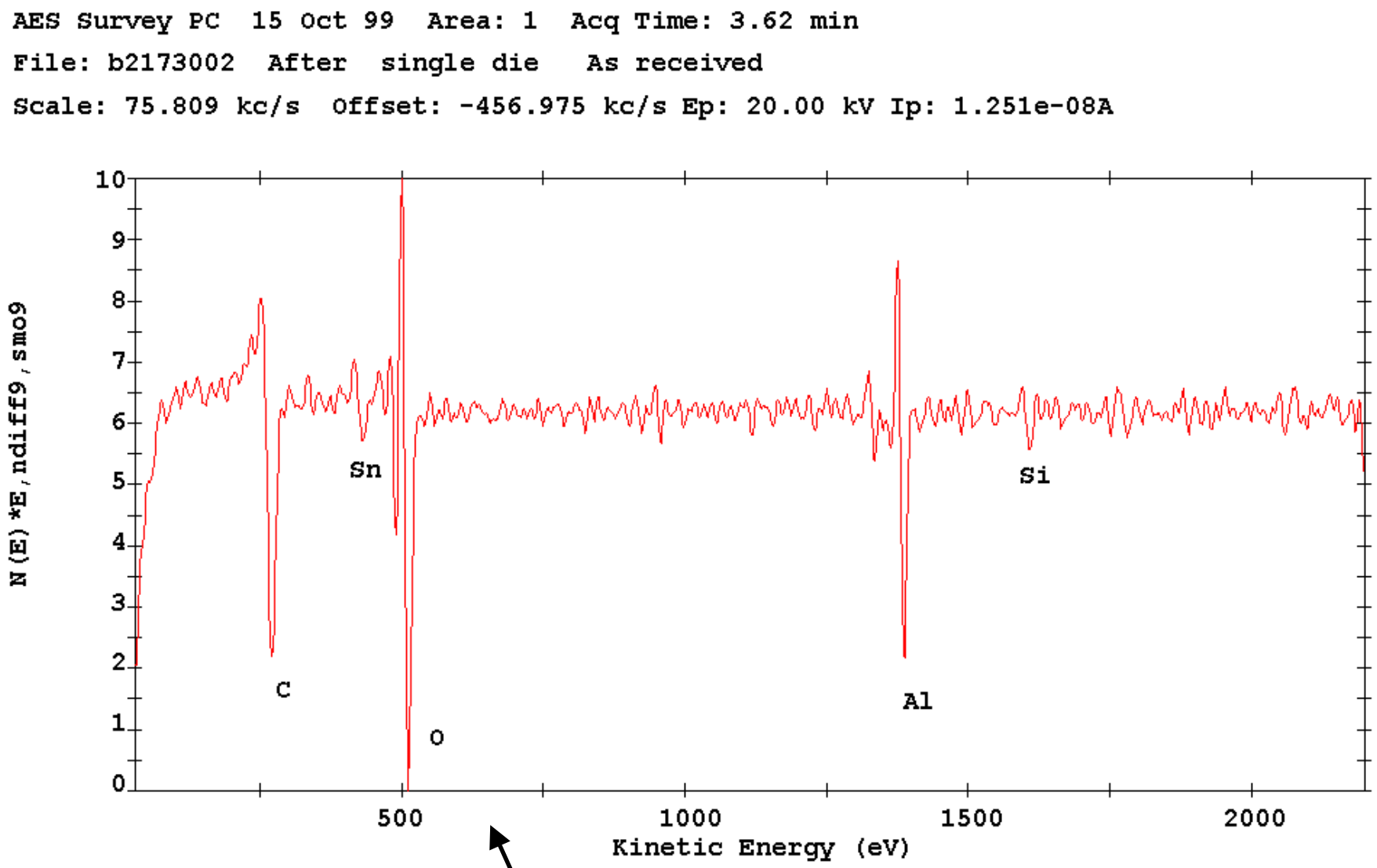
Final full survey, showing only pure Al pad.

Comments on Scan of Un-bumped Die

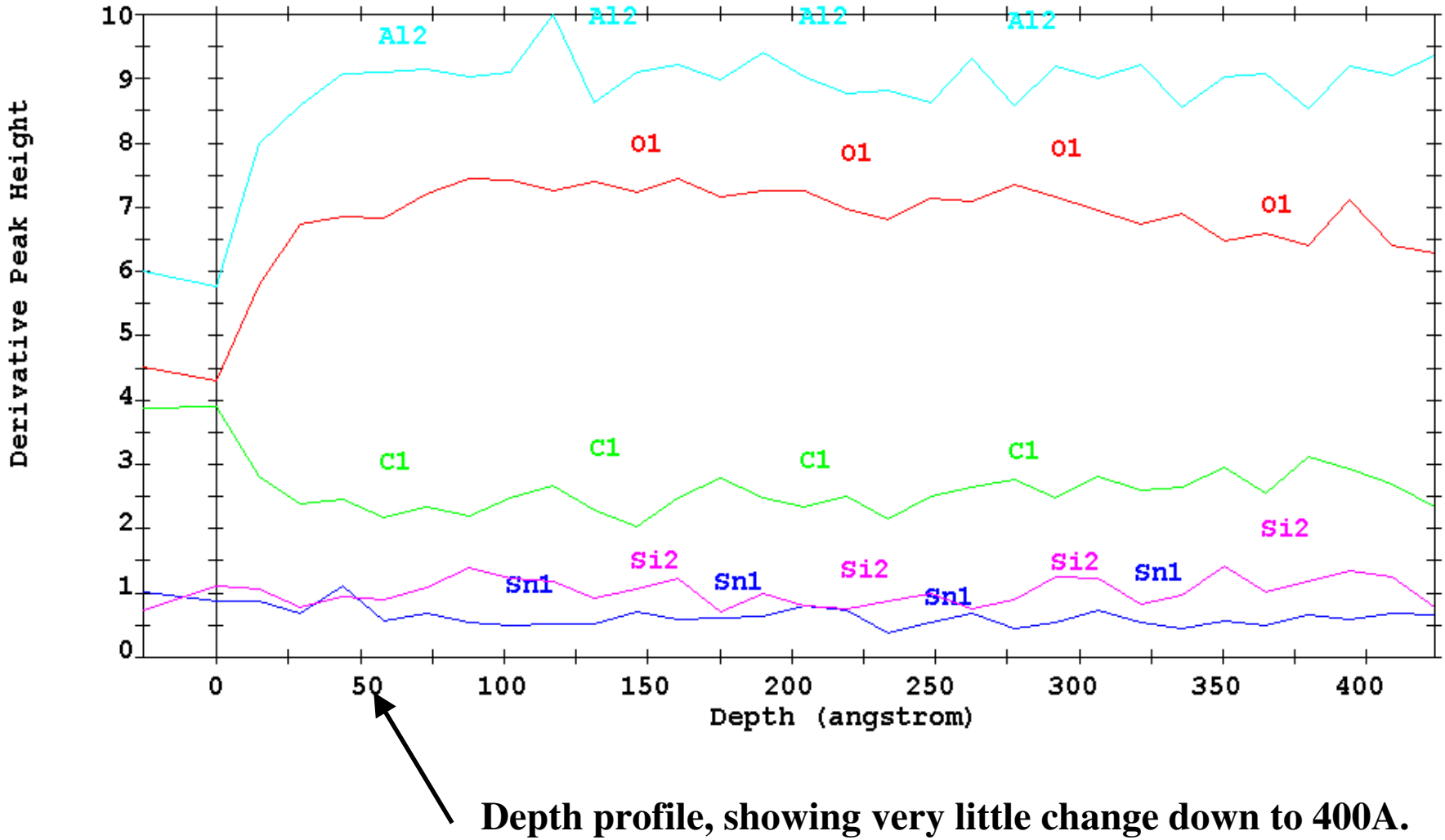
- Depth profile shows presence of Al oxide layer of about 100A thickness. This is seen as an O peak which disappears after about 100A. Also, in the Al depth profile, the character of the peak is seen to change from “non-elemental” to “elemental” (displacement of peak and secondary shoulder appears).
- A small amount of F contamination is seen in the oxide layer. This is a typical residue of the plasma etch step used to make the openings in the passivation layer for the bond-pads (normally uses CF4 or similar).
- Once the analysis passes through this Al oxide layer, there is pure elemental Al and nothing else.
- No other material is seen. This is a very normal bond-pad. Wire-bonding is usually successful up to Al oxide thicknesses of more than 200A, so this would not present any problems.

Single Die after Bump Deposition

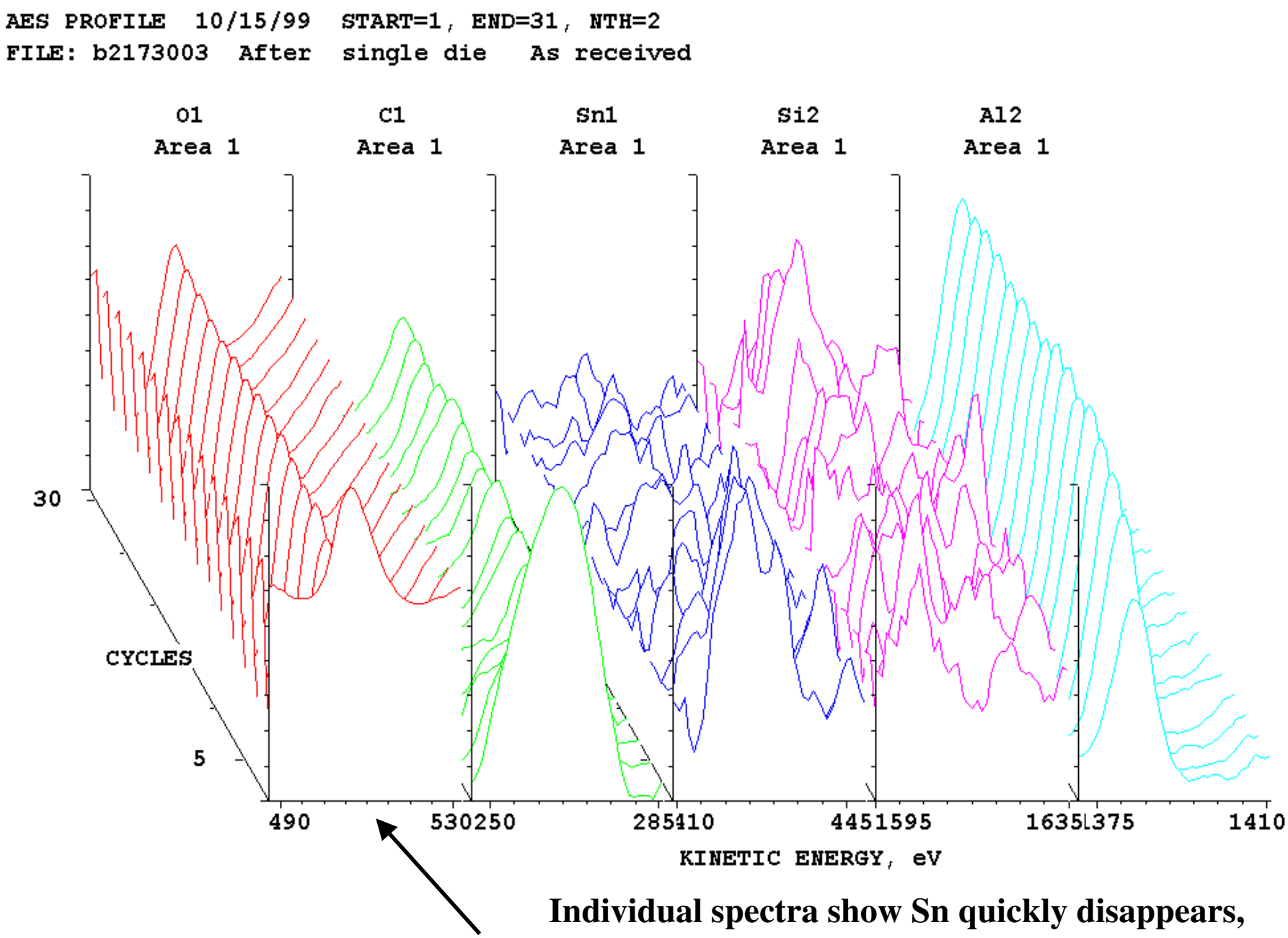




Initial full survey. Note presence of some Sn and significant C (Auger not sensitive to H).



Depth profile, showing very little change down to 400A. Normally, would have reached Al pad at this depth.

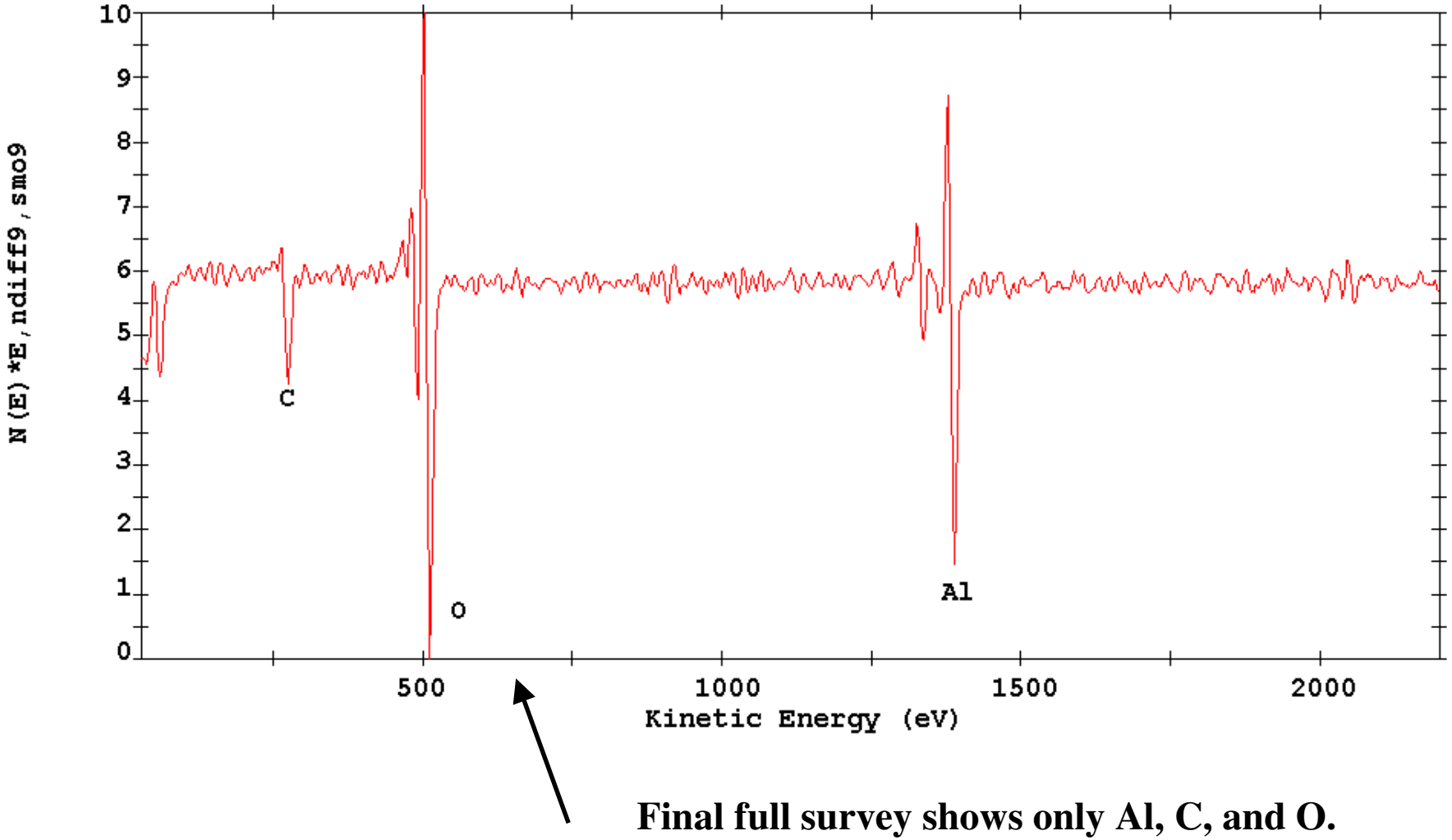


Individual spectra show Sn quickly disappears, leaving Al (non-elemental), O and C.

AES Survey PC 15 Oct 99 Area: 1 Acq Time: 3.62 min

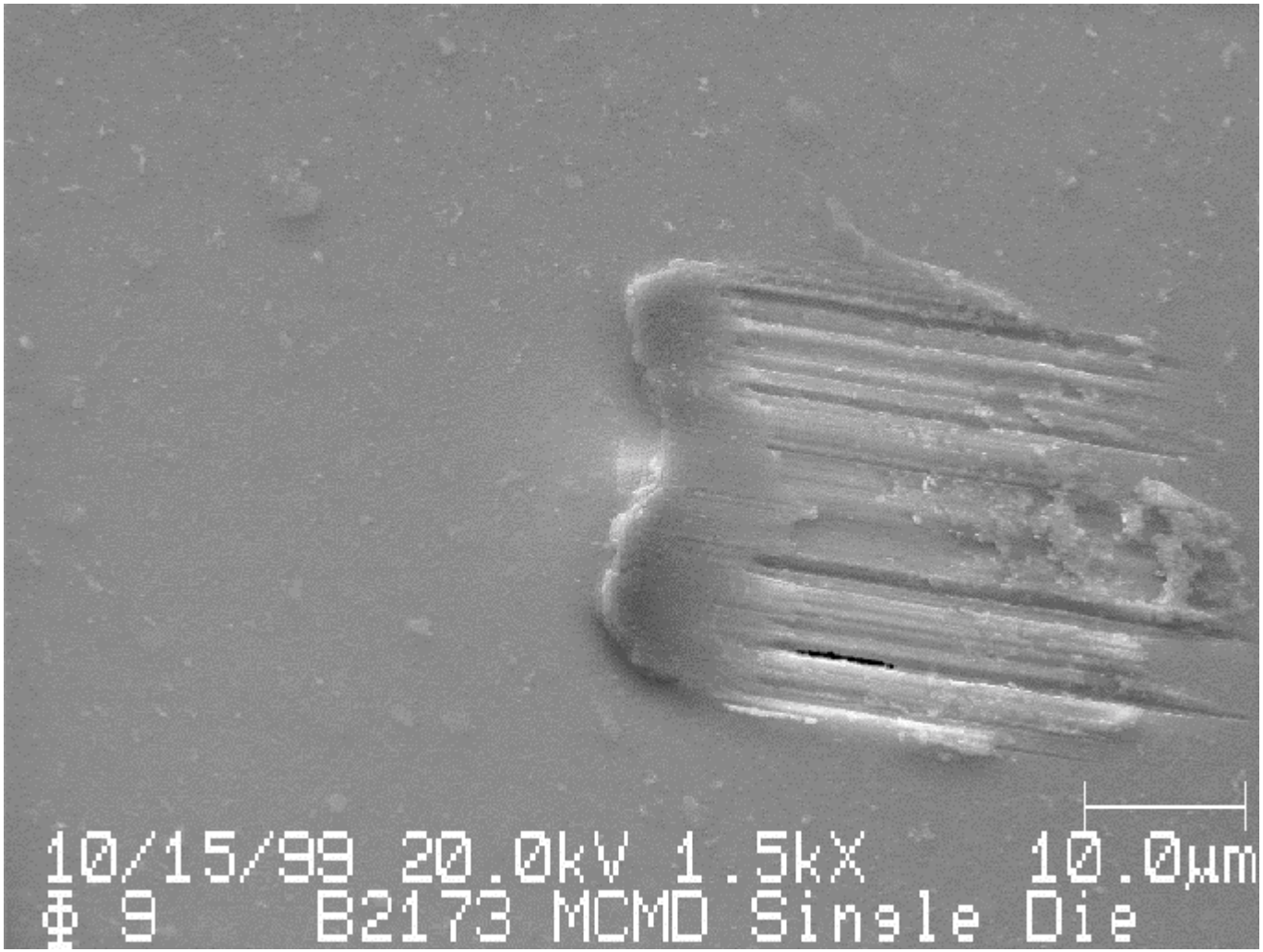
File: b2173004 After single die After profile

Scale: 106.329 kc/s Offset: -608.215 kc/s Ep: 20.00 kV Ip: 1.251e-08A

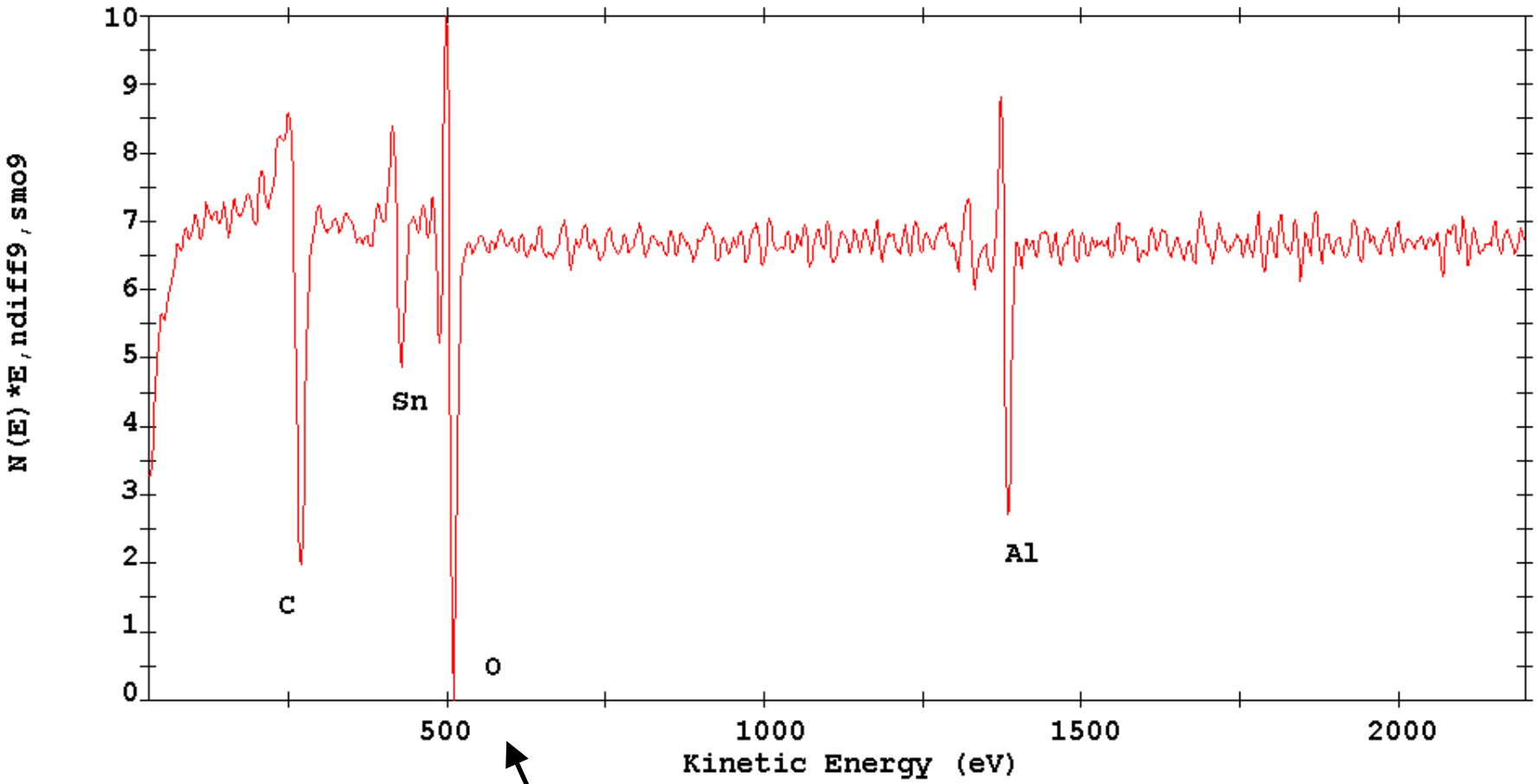


Final full survey shows only Al, C, and O. The observed Al peak is not elemental Al expected from clean pad.

Single Die MCM-D assembly



AES Survey PC 15 Oct 99 Area: 1 Acq Time: 3.62 min
File: b21730010 MCMD single die As received
Scale: 62.051 kc/s Offset: -403.095 kc/s Ep: 20.00 kV Ip: 1.251e-08A

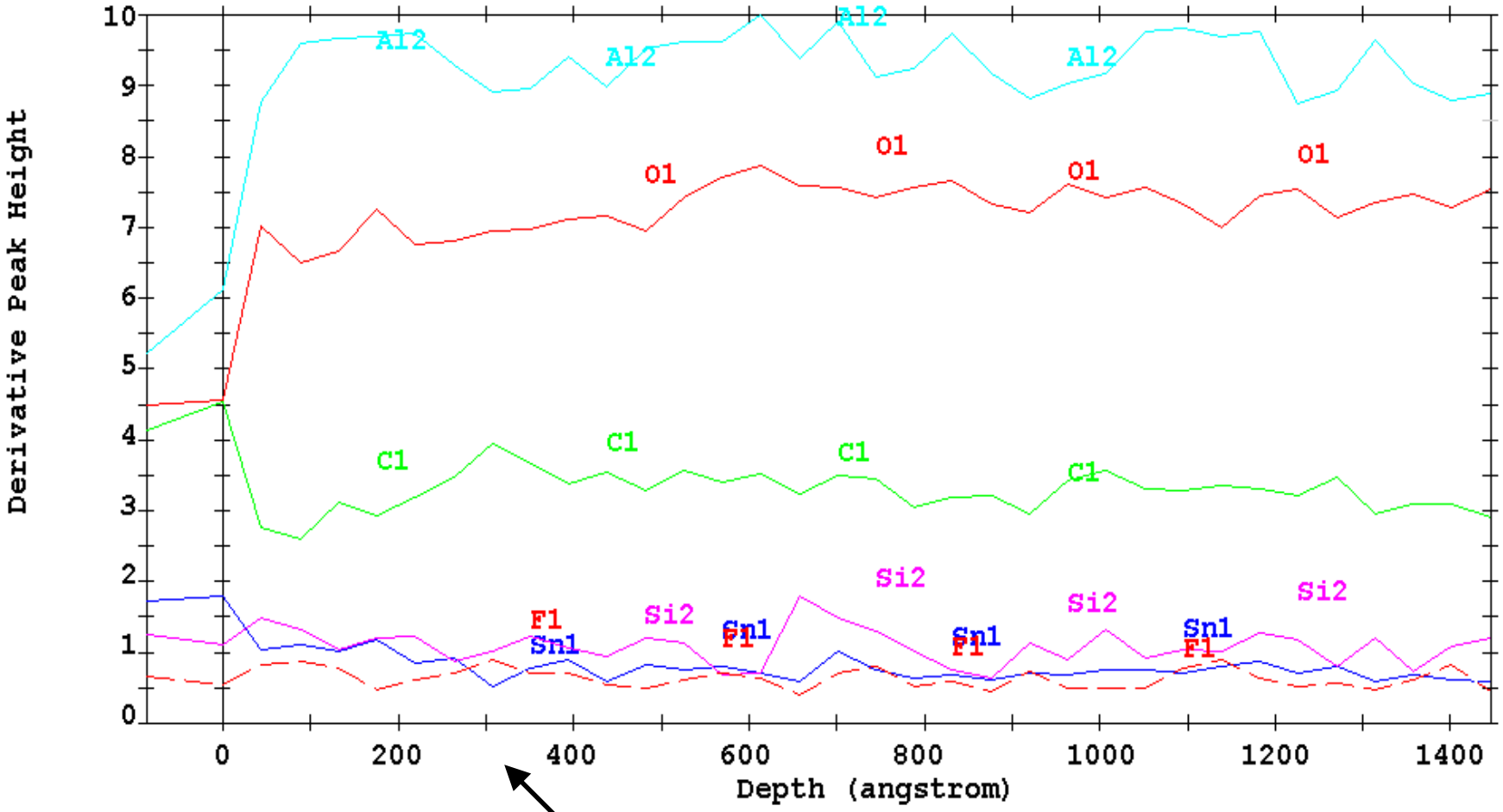


Initial survey again shows some Sn and lots of C.

AES Profile PC 15 Oct 99 Region: 6(F1) Area: 1 Sput Time: 9.90 min

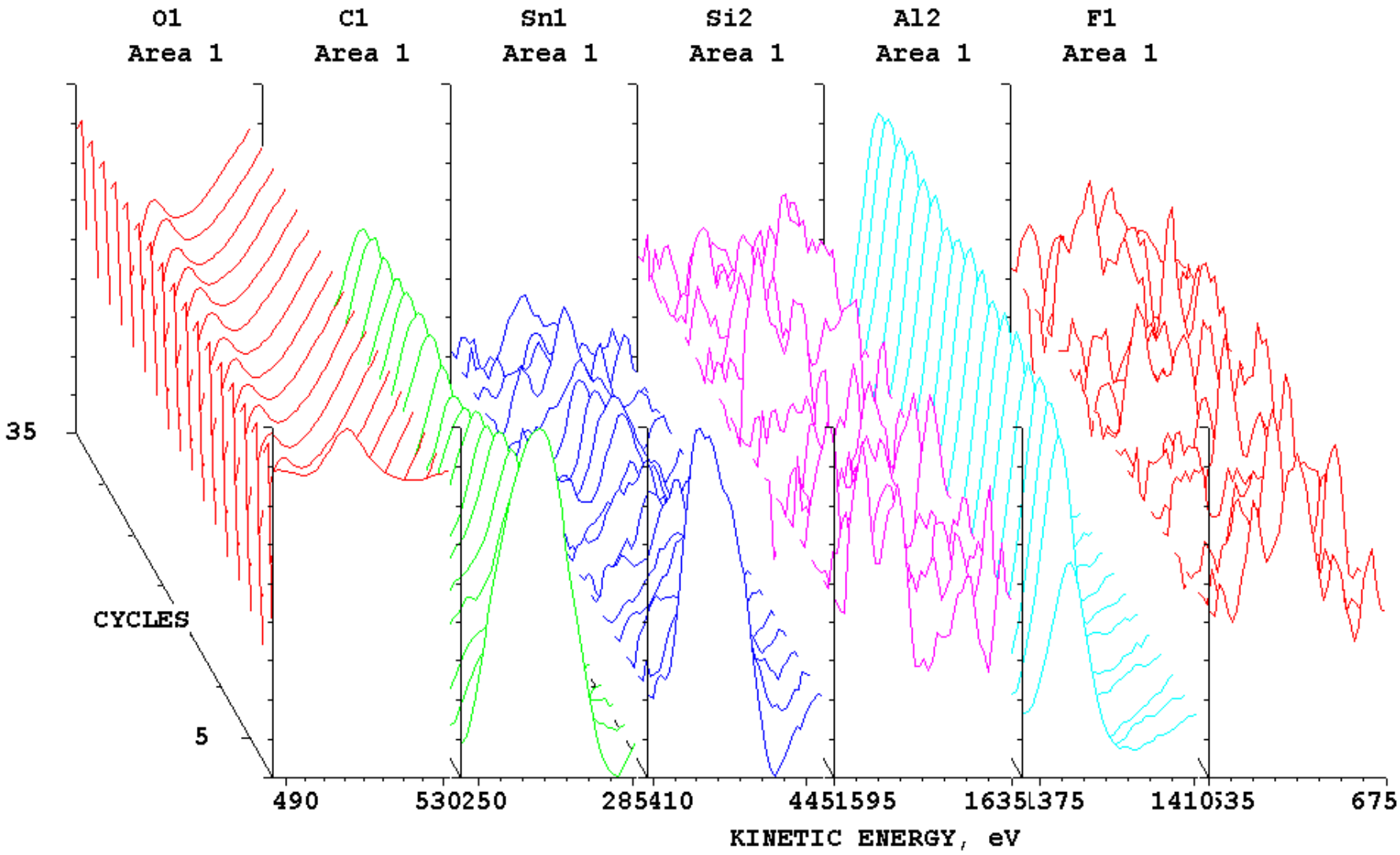
File: b21730011 MCMD single die As received

Scale: 236.390 kc/s Offset: 0.000 kc/s Ep: 20.00 kV Ip: 1.251e-08A



Depth profile done in larger steps, and extended to much greater depth. Still no end to contamination was found.

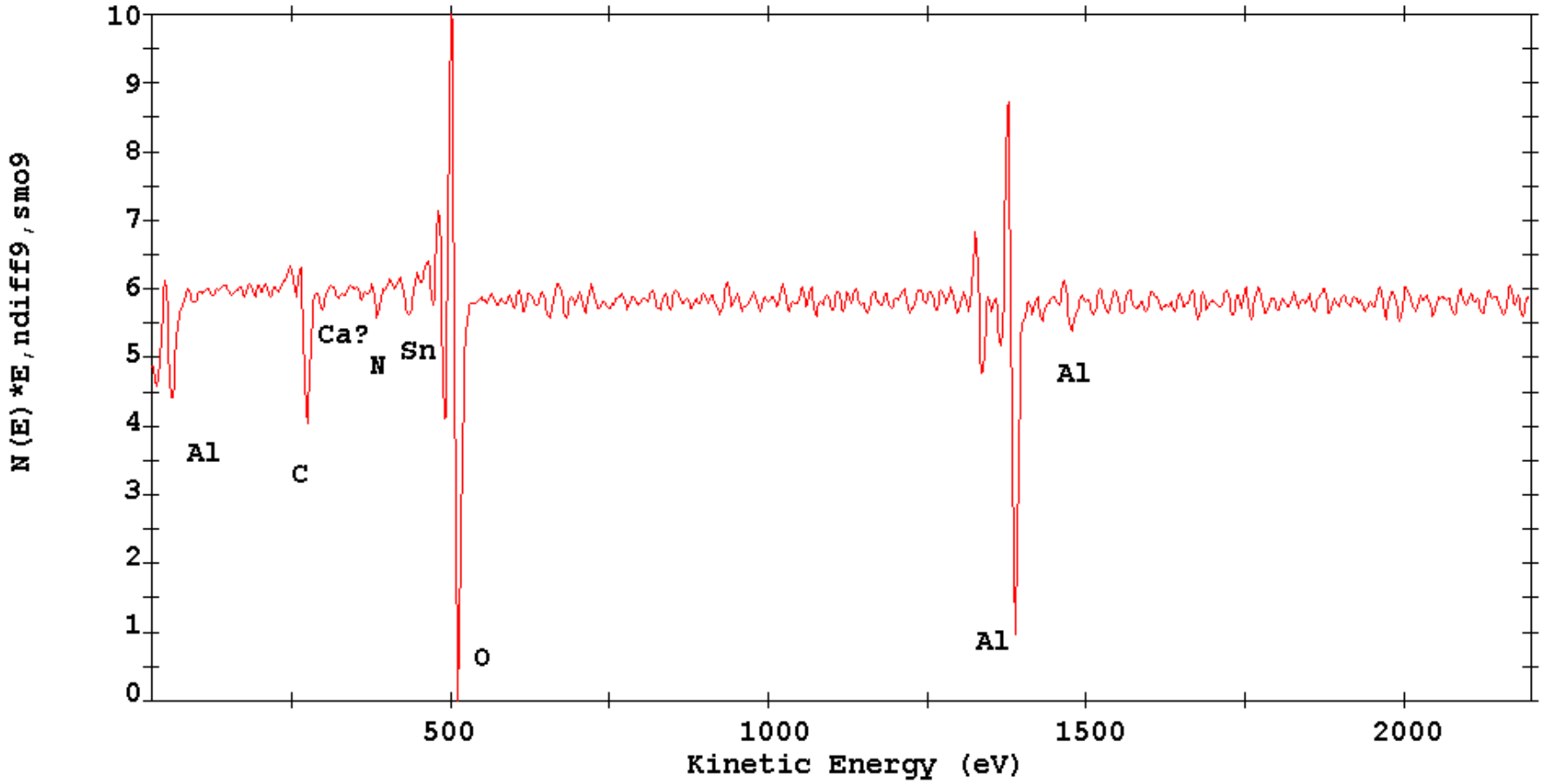
AES PROFILE 10/15/99 START=1, END=35, NTH=2
FILE: b21730011 MCMD single die As received



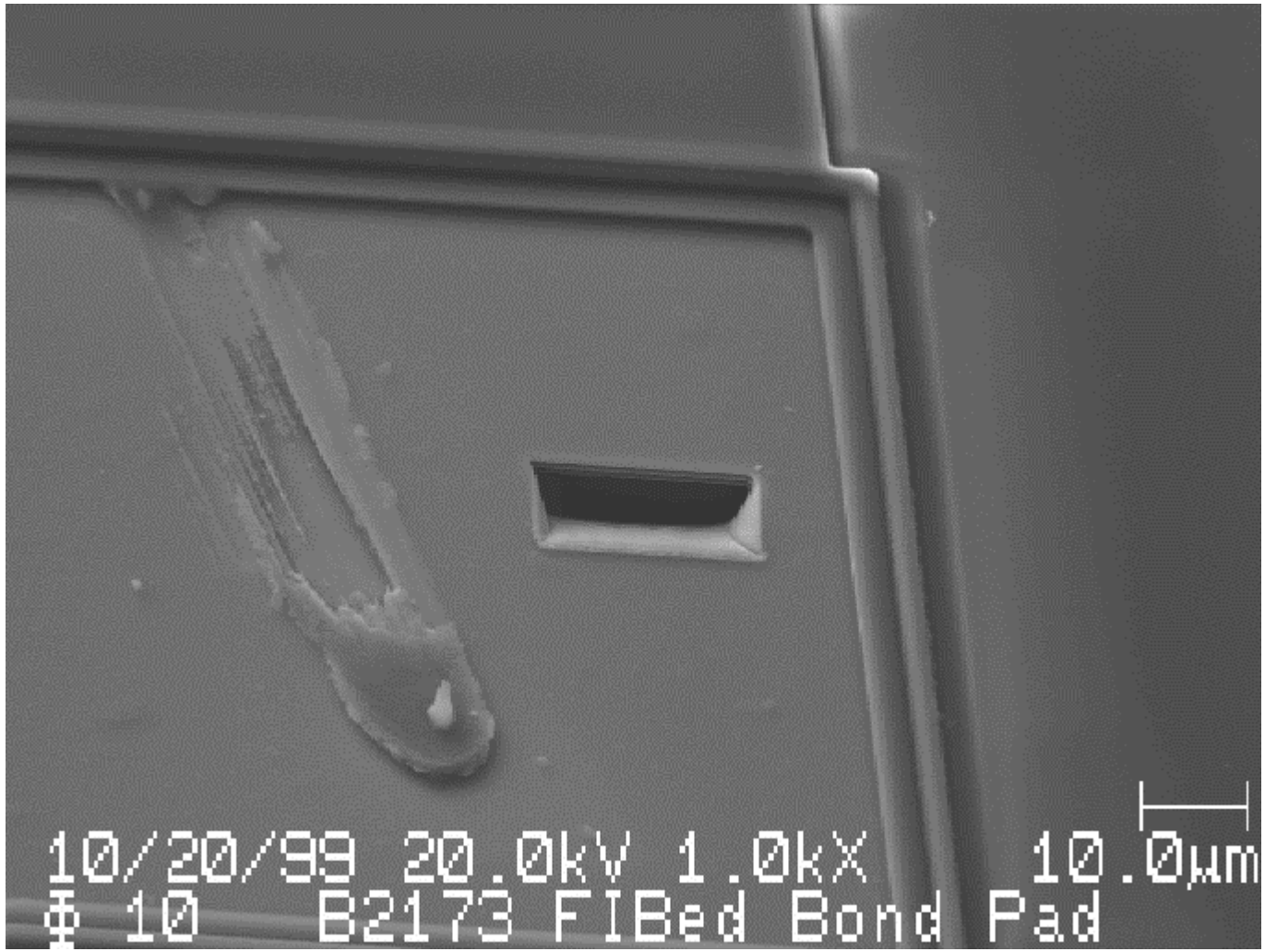
AES Survey PC 15 Oct 99 Area: 1 Acq Time: 3.62 min

File: b21730012 MCMD single die After profile

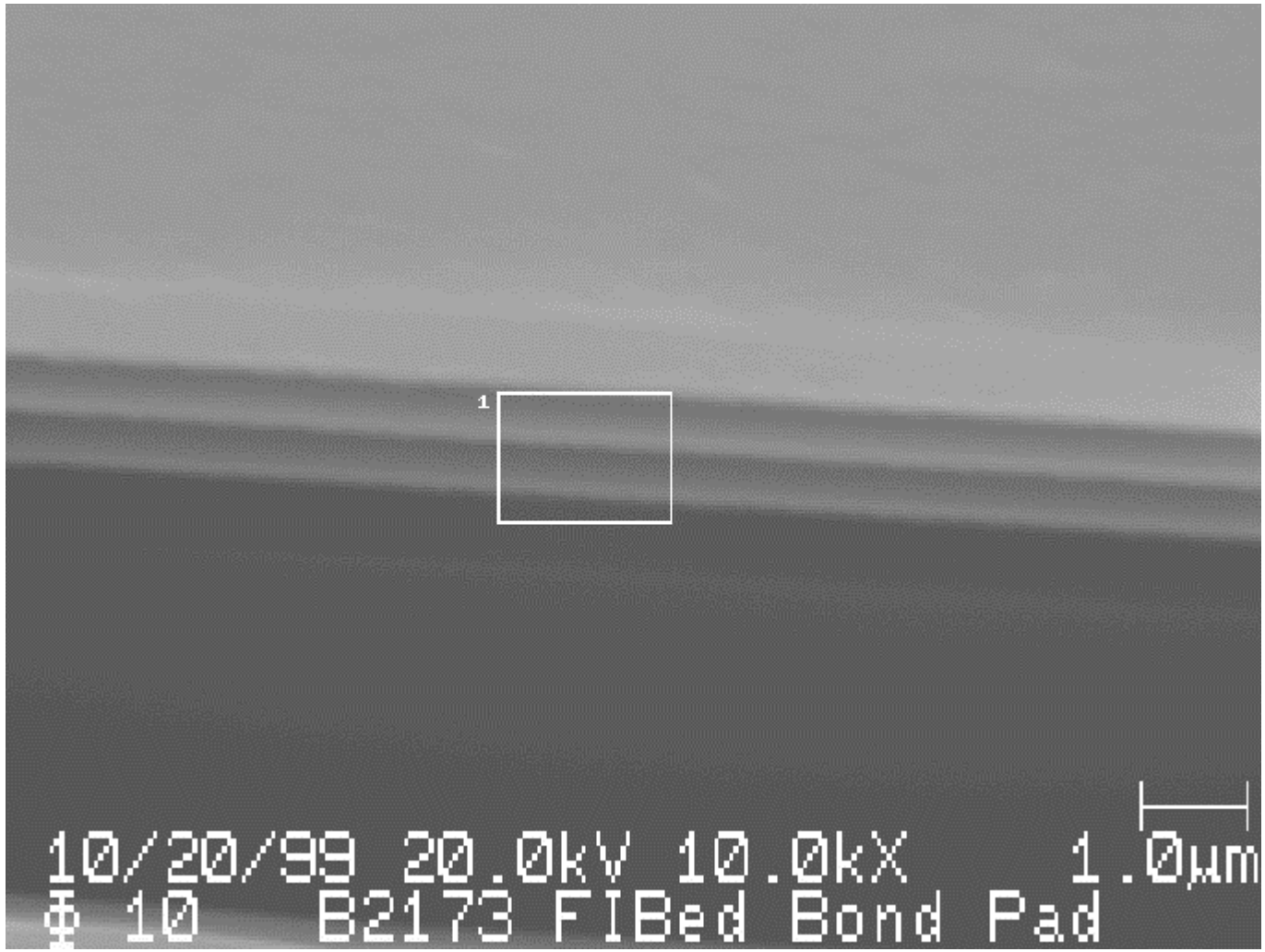
Scale: 89.272 kc/s Offset: -509.220 kc/s Ep: 20.00 kV Ip: 1.251e-08A



FIBed Bond Pad on MCM-D assembly



FIBed Bond Pad on MCM-D Assembly

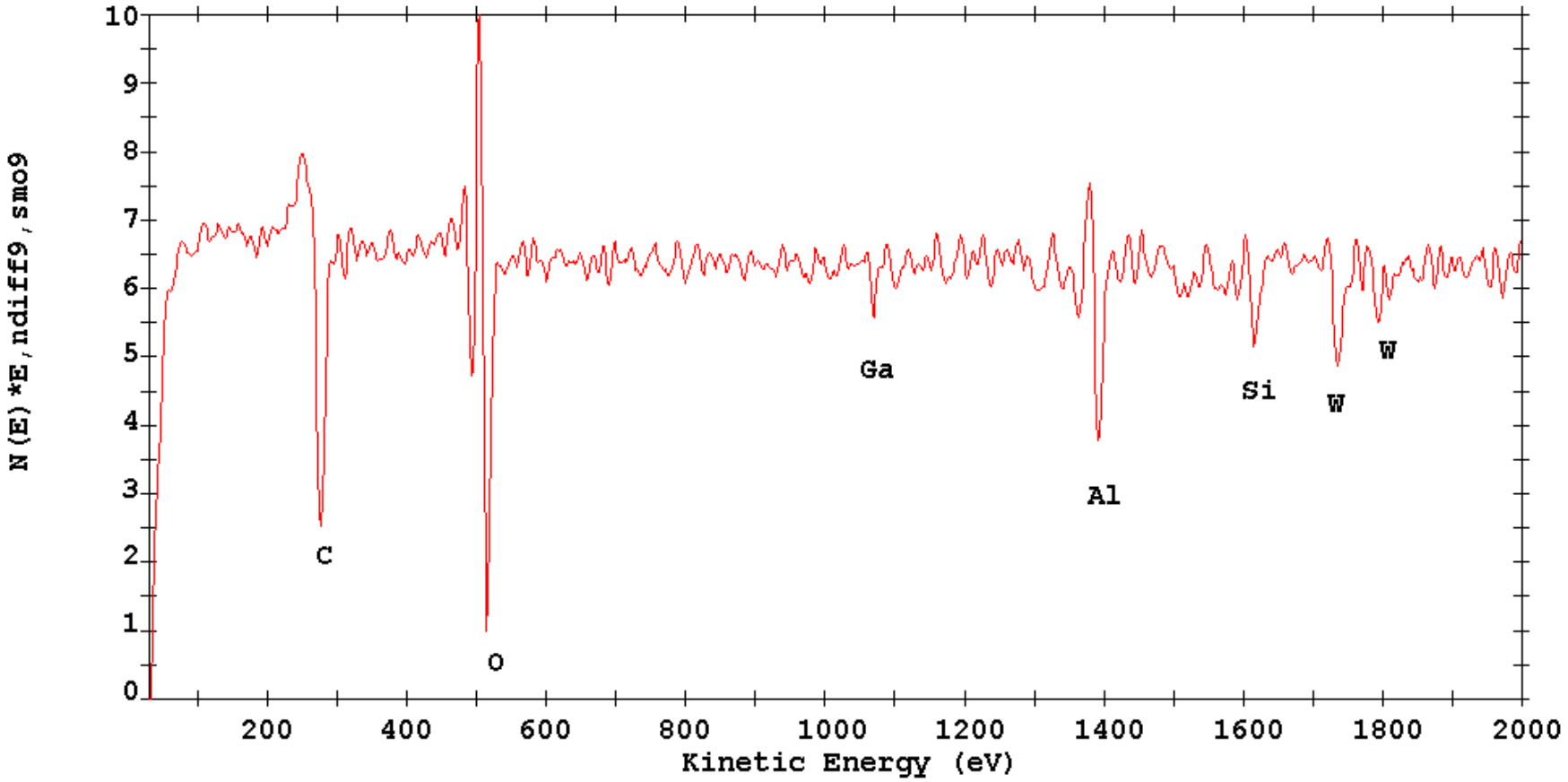


Clearly see presence of 3 Al layers in pad.

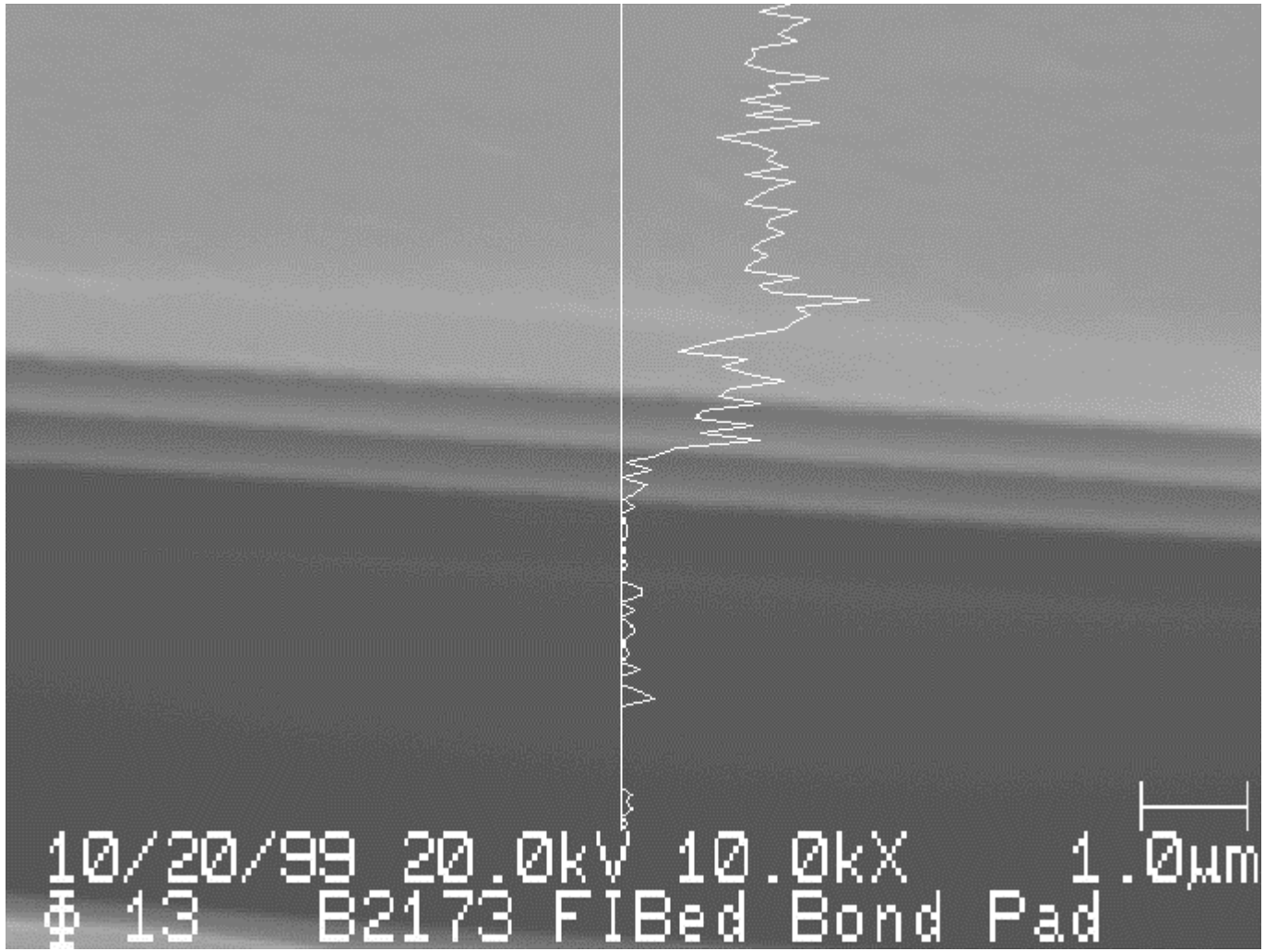
AES Survey PC 20 Oct 99 Area: 1 Acq Time: 3.29 min

File: b2173012 FIBed bond pad As received

Scale: 57.028 kc/s Offset: -351.625 kc/s Ep: 20.00 kV Ip: 8.994e-09A



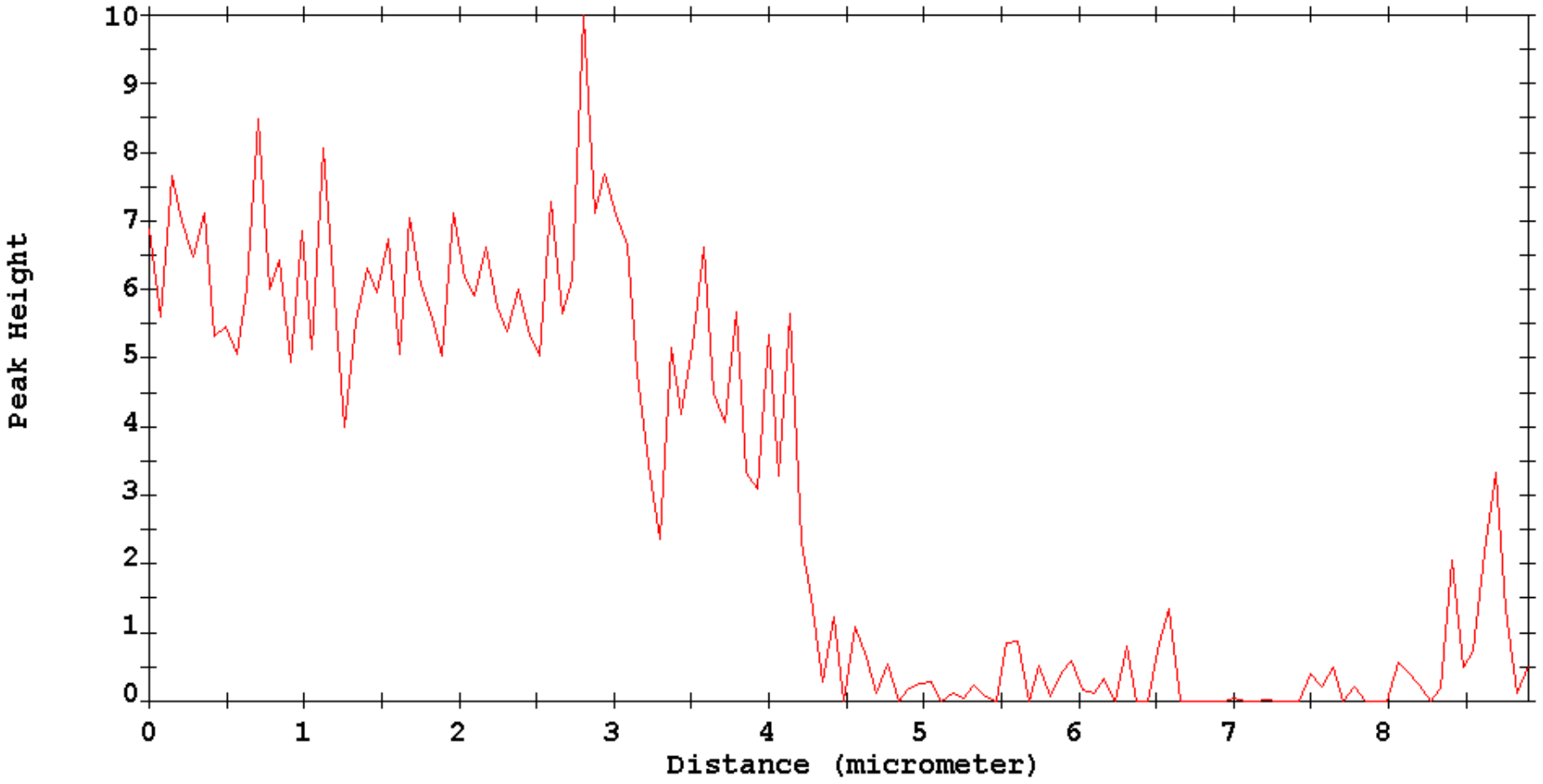
FIBed Bond Pad Al line



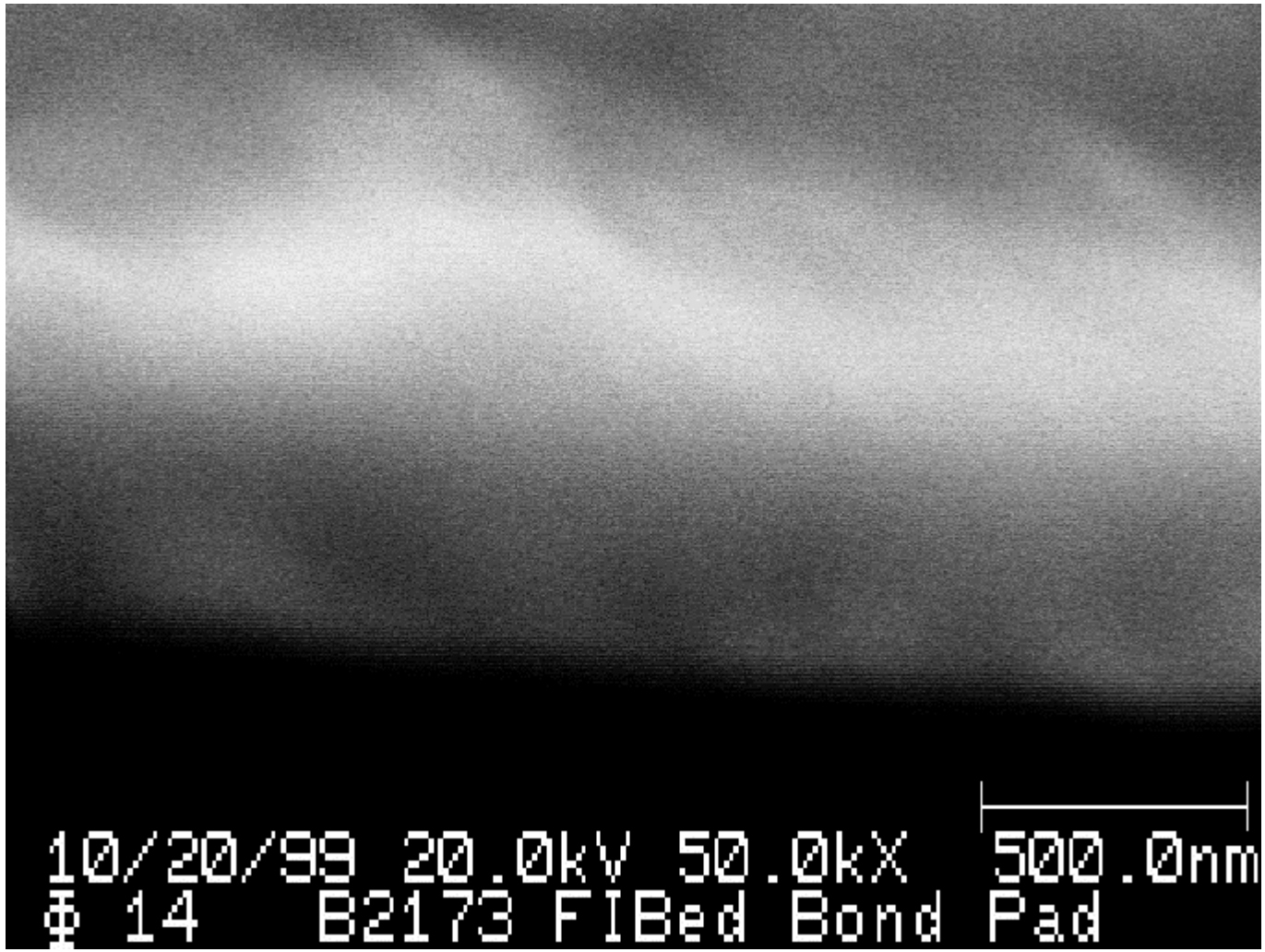
AES Line PC 20 Oct 99 Region: 1(Al2) Line: 1 Acq Time: 0.43 min

File: b2173013 FIBed bond pad As received

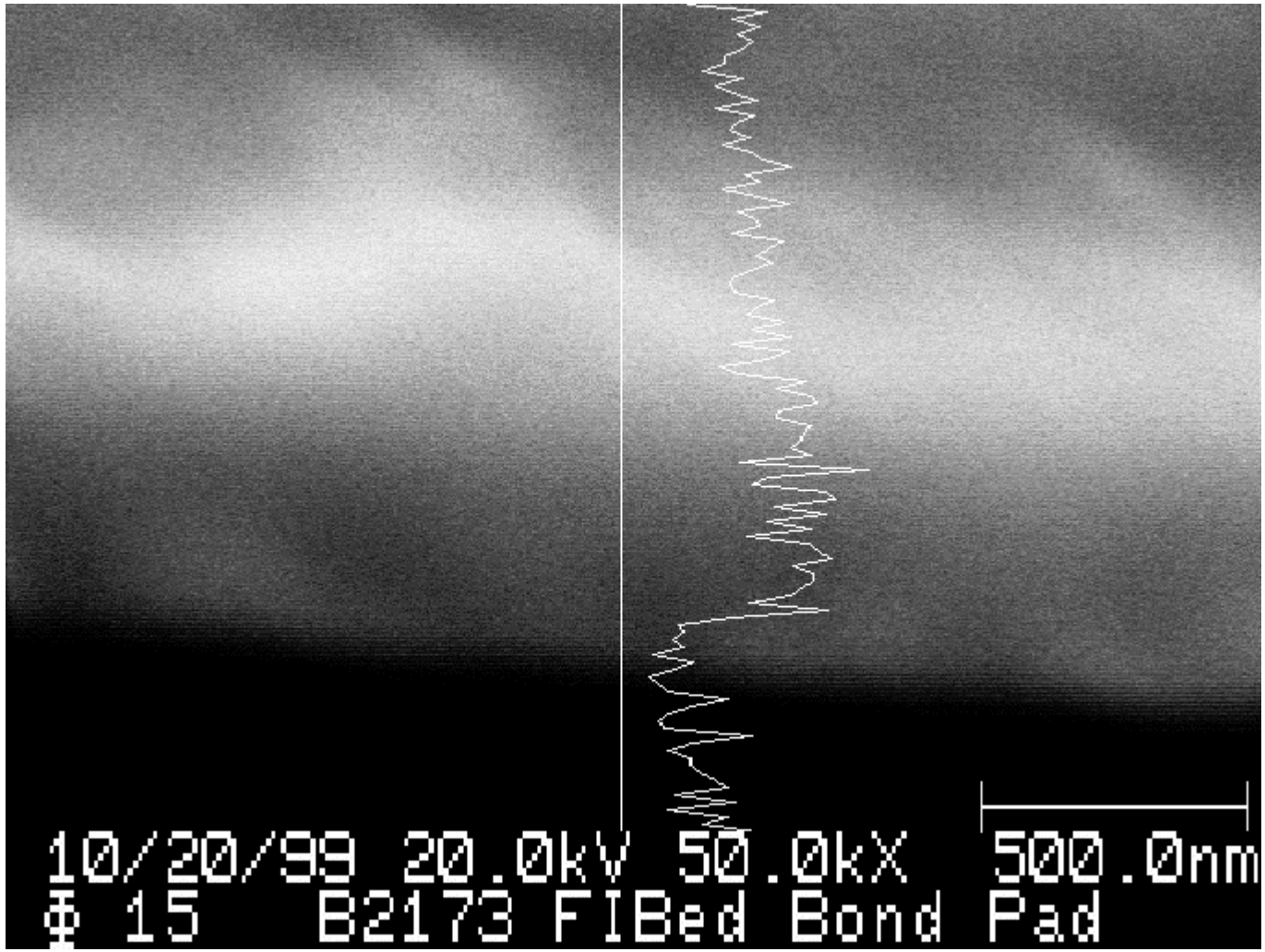
Scale: 2.303 kc/s Offset: 0.000 kc/s Ep: 20.00 kV Ip: 8.994e-09A



FIBed Bond Pad



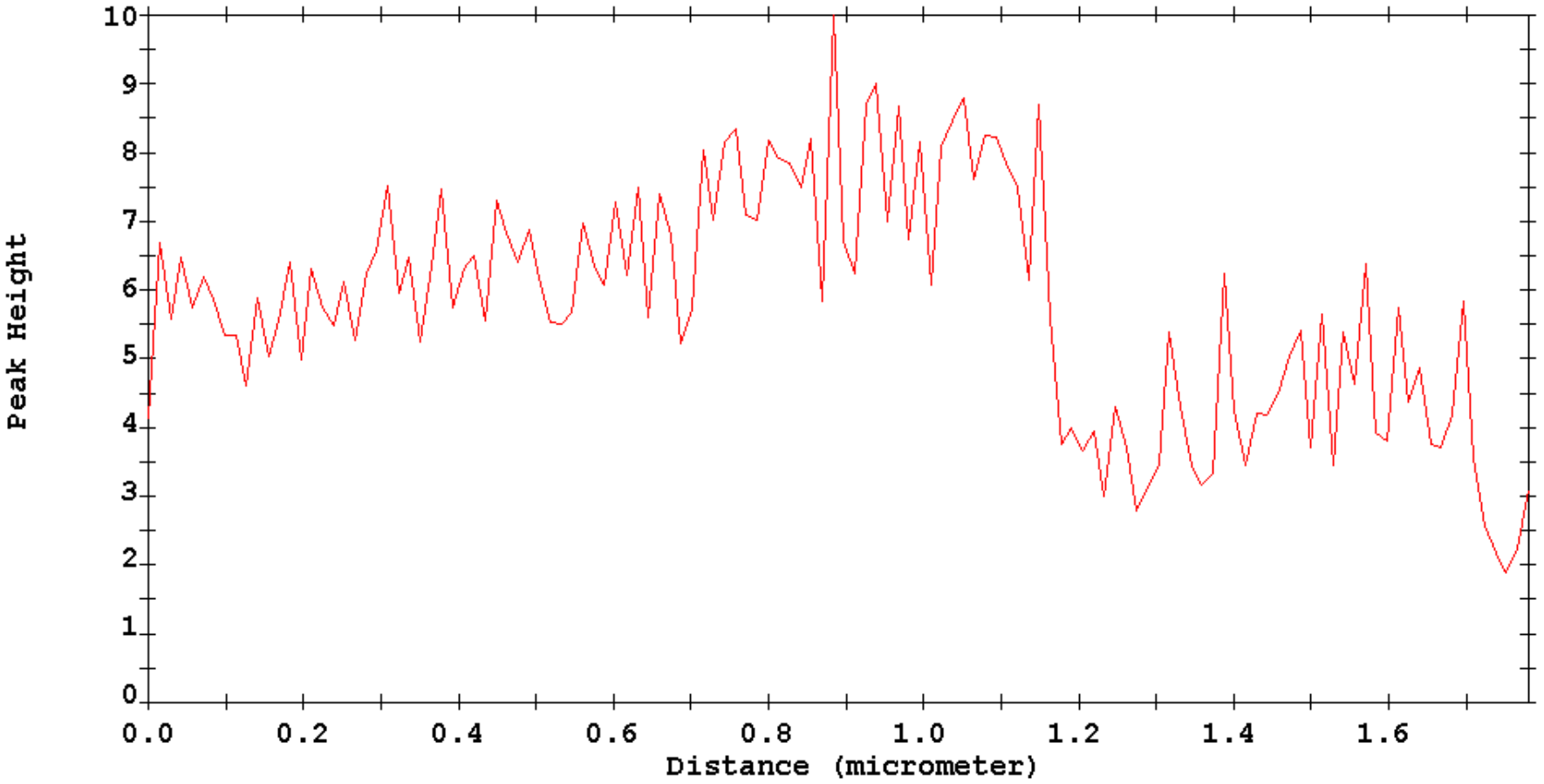
FIBed Bond Pad Al line



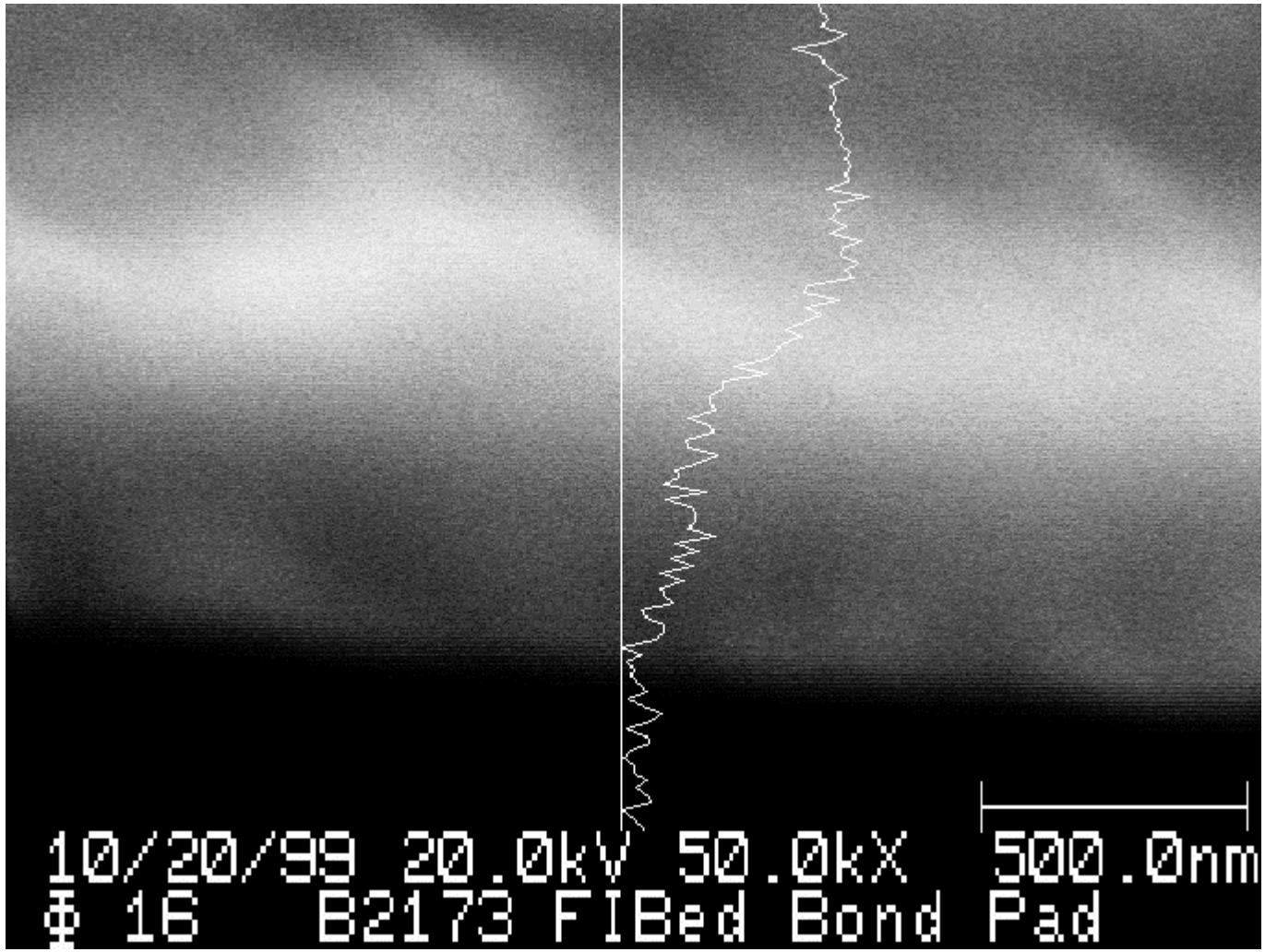
AES Line PC 20 Oct 99 Region: 1(Al2) Line: 1 Acq Time: 0.43 min

File: b2173015 FIBed bond pad As received

Scale: 3.071 kc/s Offset: 0.000 kc/s Ep: 20.00 kV Ip: 8.994e-09A



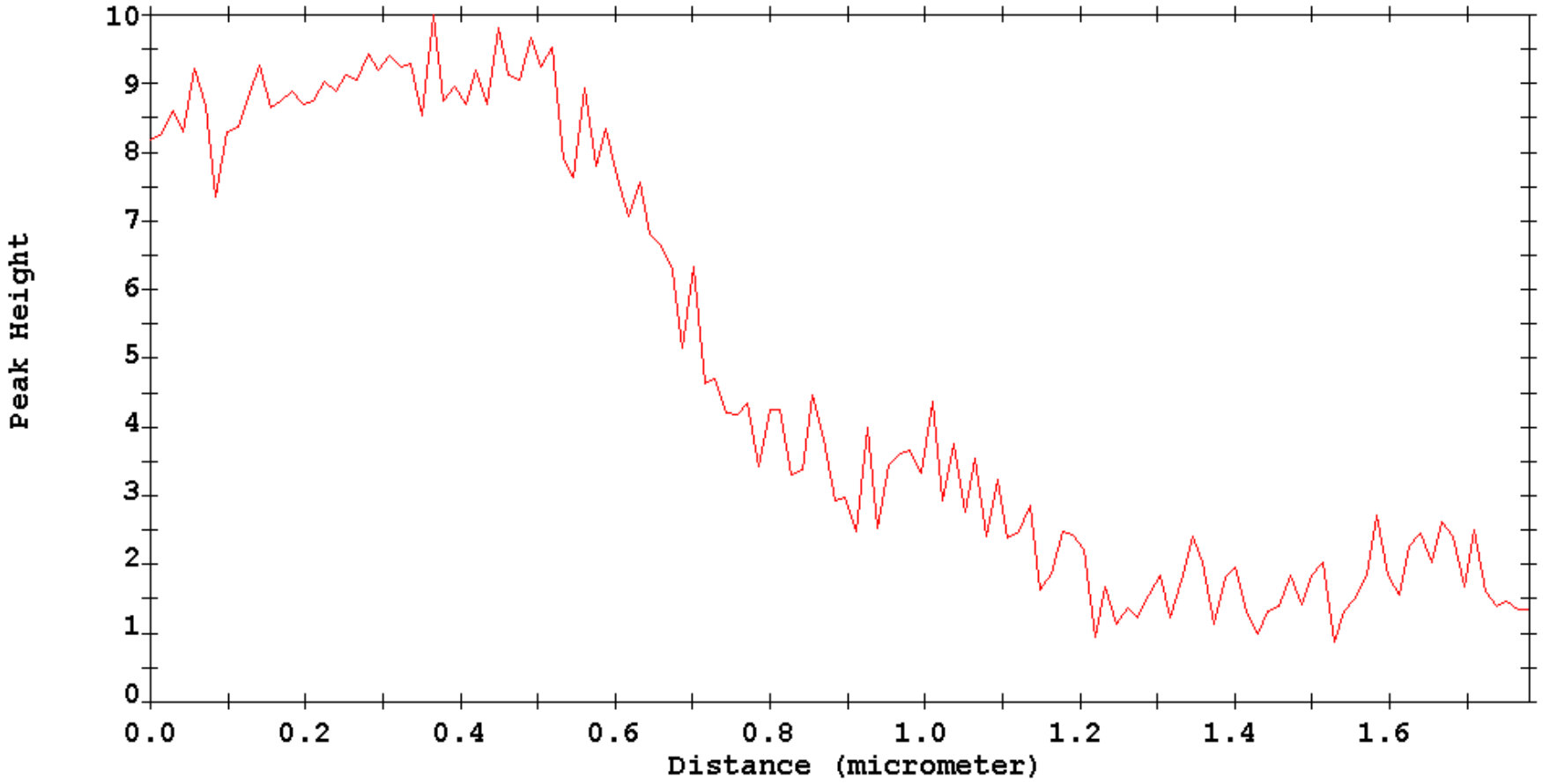
FIBed Bond Pad O line



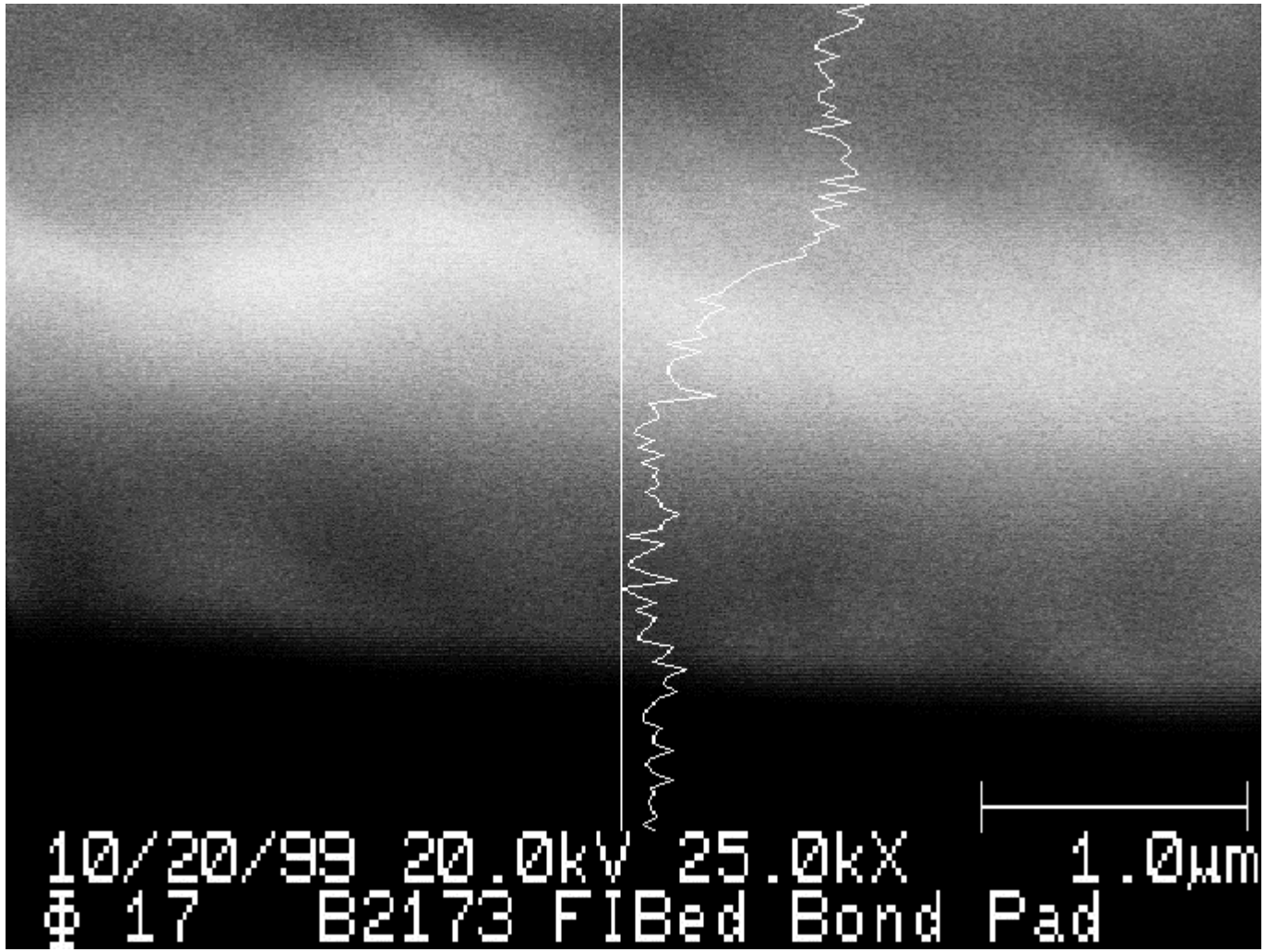
AES Line PC 20 Oct 99 Region: 1(01) Line: 1 Acq Time: 0.43 min

File: b2173016 FIBed bond pad As received

Scale: 4.809 kc/s Offset: 0.000 kc/s Ep: 20.00 kV Ip: 8.994e-09A



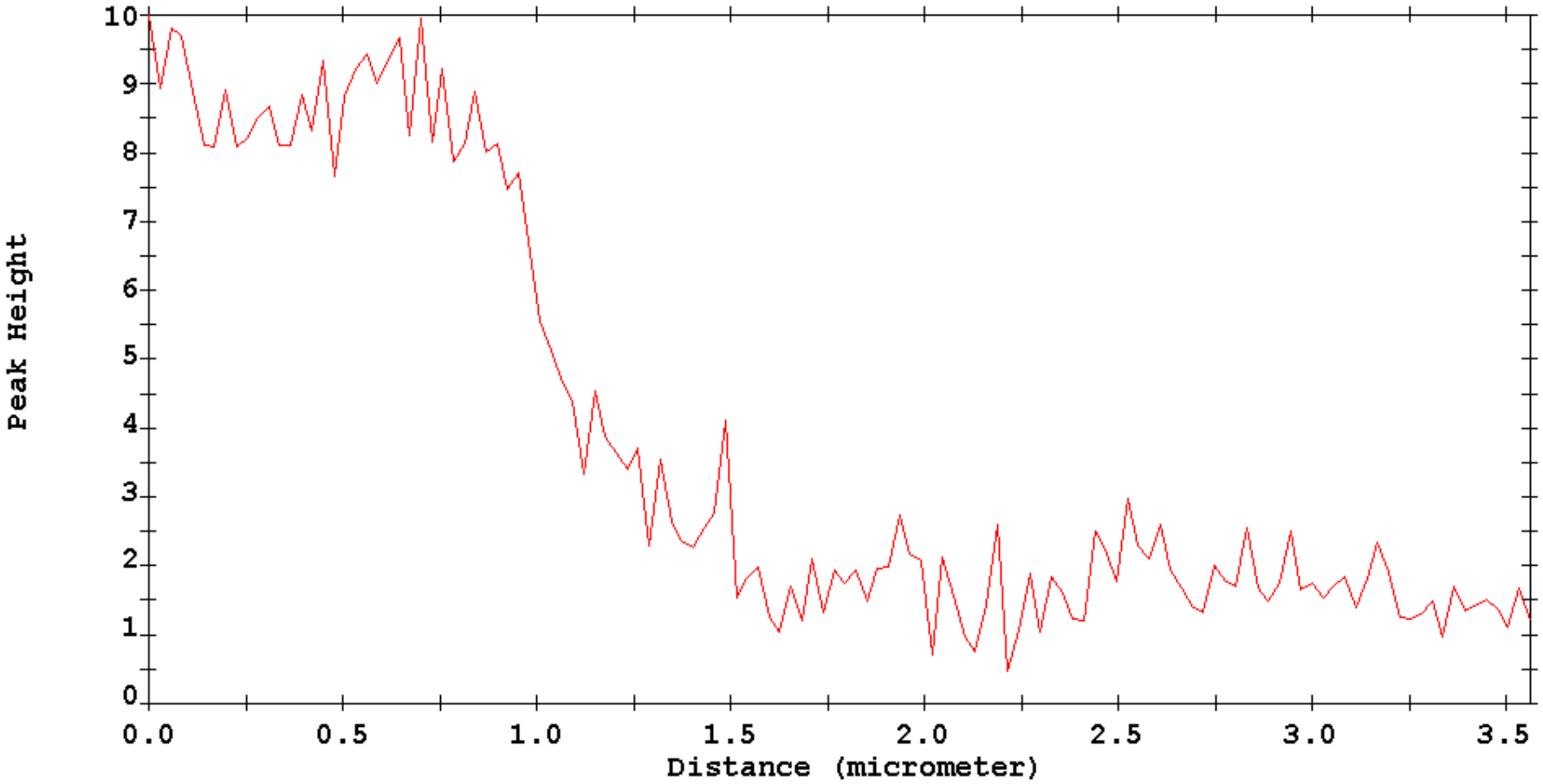
FIBed Bond Pad O line



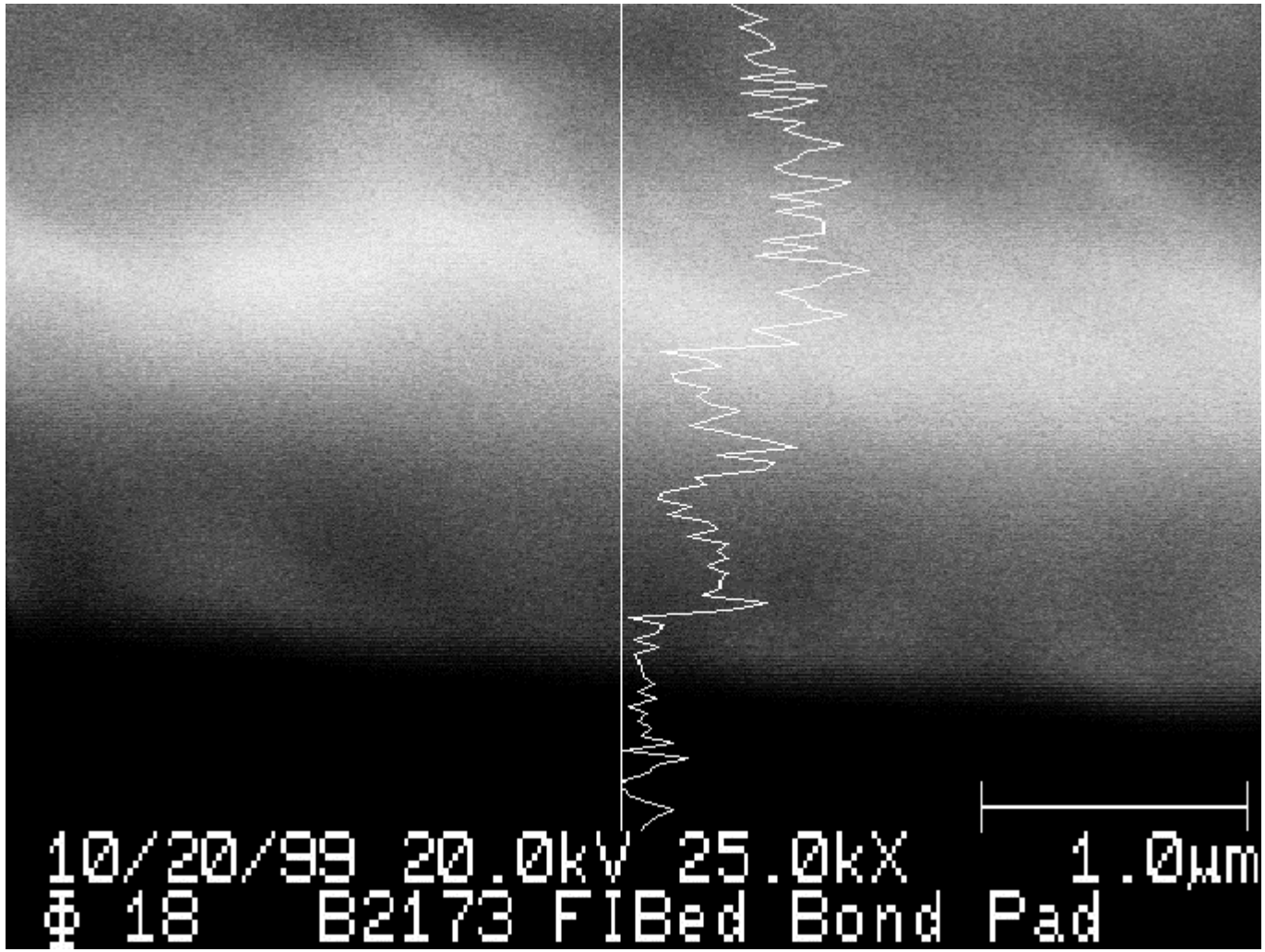
AES Line PC 20 Oct 99 Region: 1(01) Line: 1 Acq Time: 0.43 min

File: b2173017 FIBed bond pad As received

Scale: 5.015 kc/s Offset: 0.000 kc/s Ep: 20.00 kV Ip: 8.994e-09A



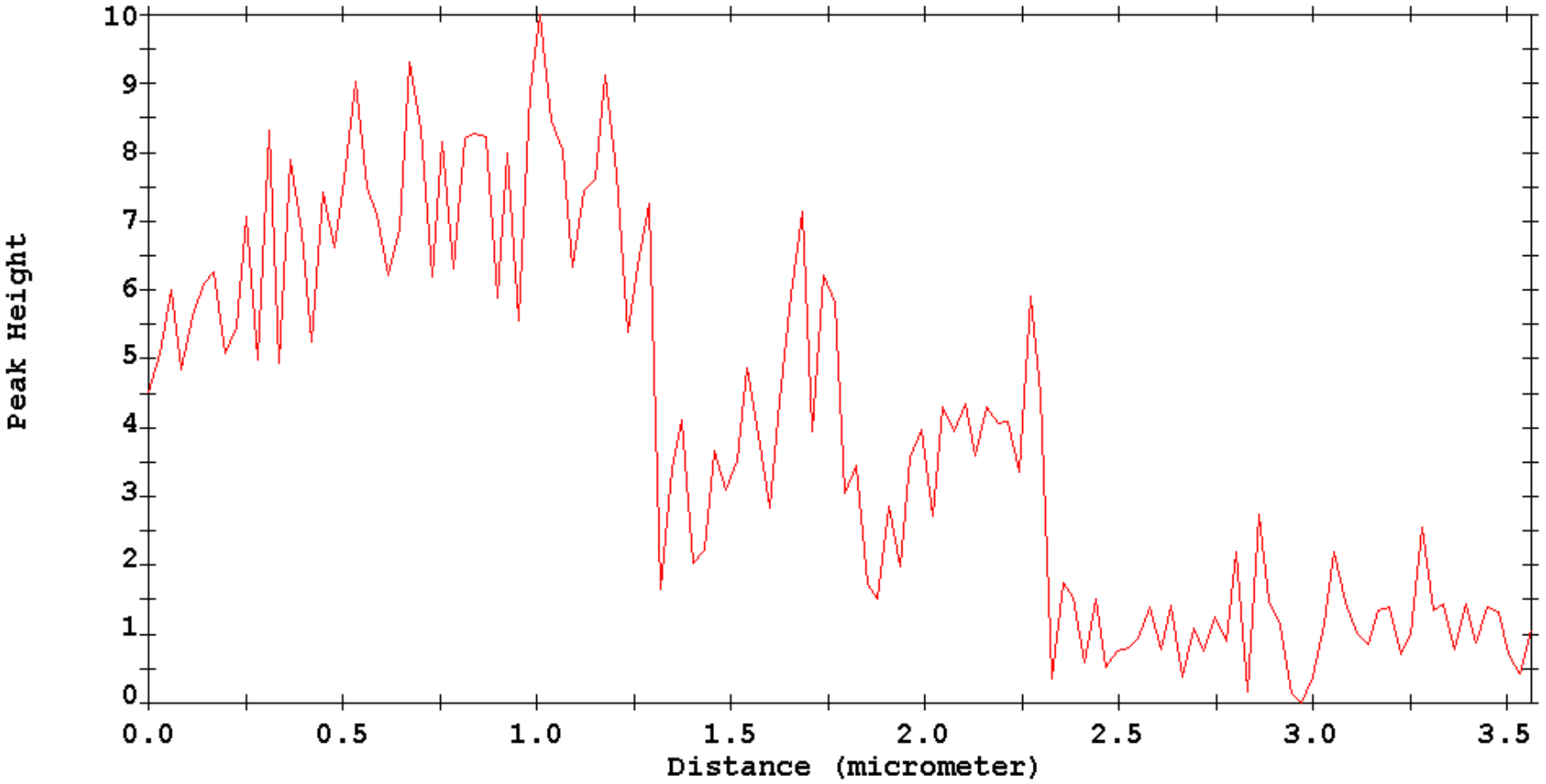
FIBed Bond Pad Al line



AES Line PC 20 Oct 99 Region: 1(Al2) Line: 1 Acq Time: 0.43 min

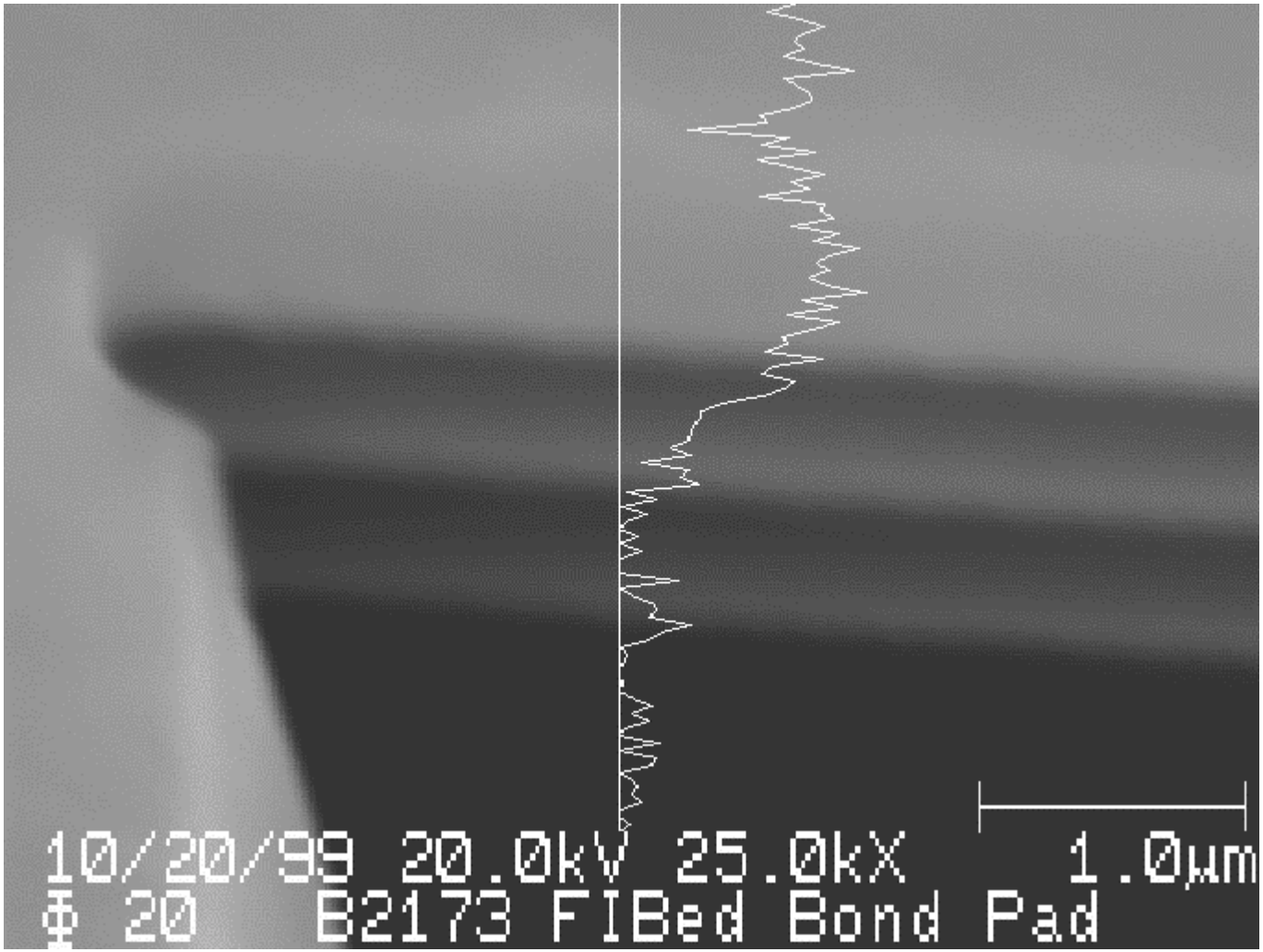
File: b2173018 FIBed bond pad As received

Scale: 2.361 kc/s Offset: 0.000 kc/s Ep: 20.00 kV Ip: 8.994e-09A



FIBed Bond Pad

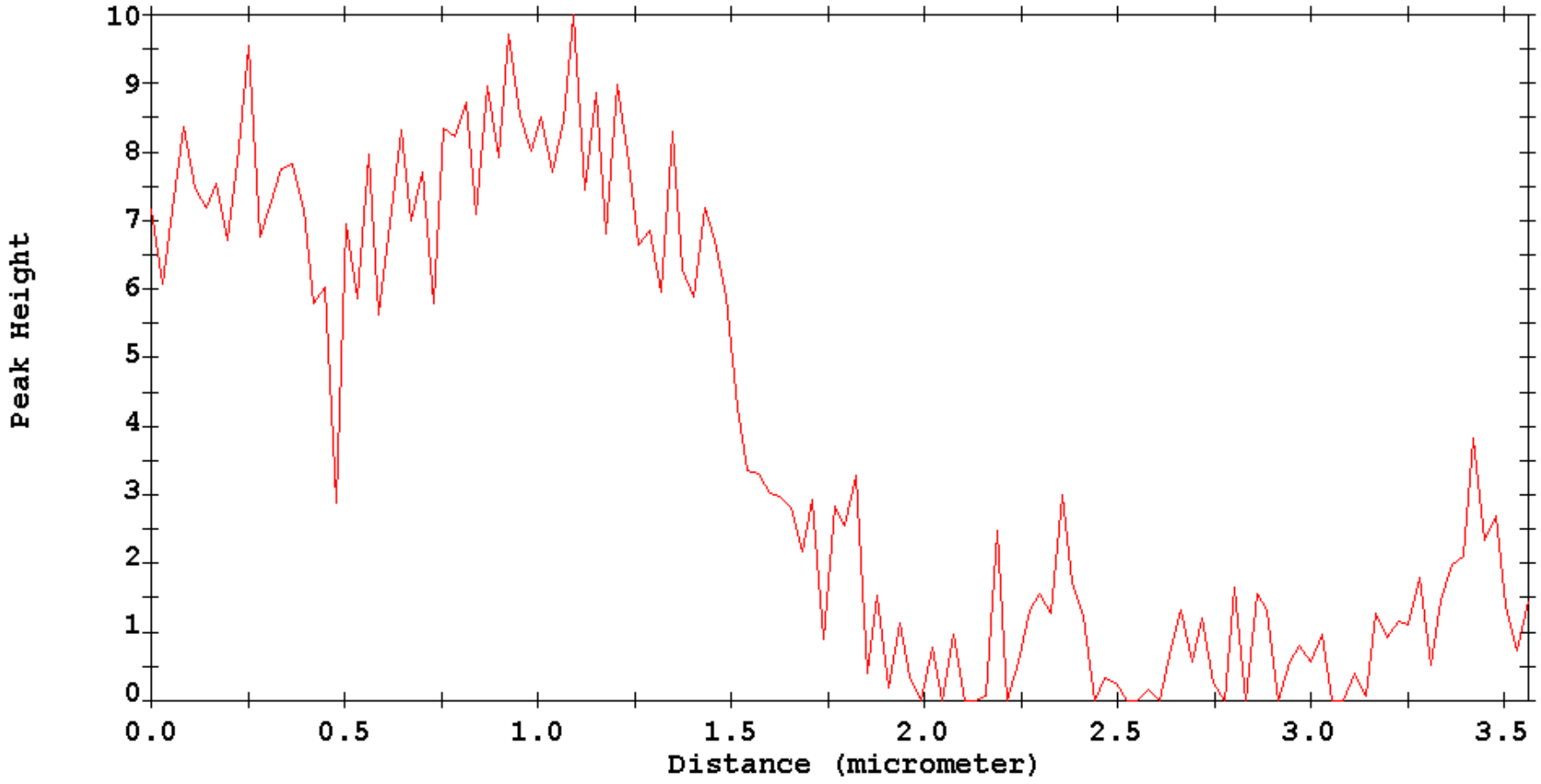
FIBed Bond Pad C line



AES Line PC 20 Oct 99 Region: 1(C1) Line: 1 Acq Time: 0.85 min

File: b2173020 FIBed bond pad As received

Scale: 1.294 kc/s Offset: 0.000 kc/s Ep: 20.00 kV Ip: 8.994e-09A

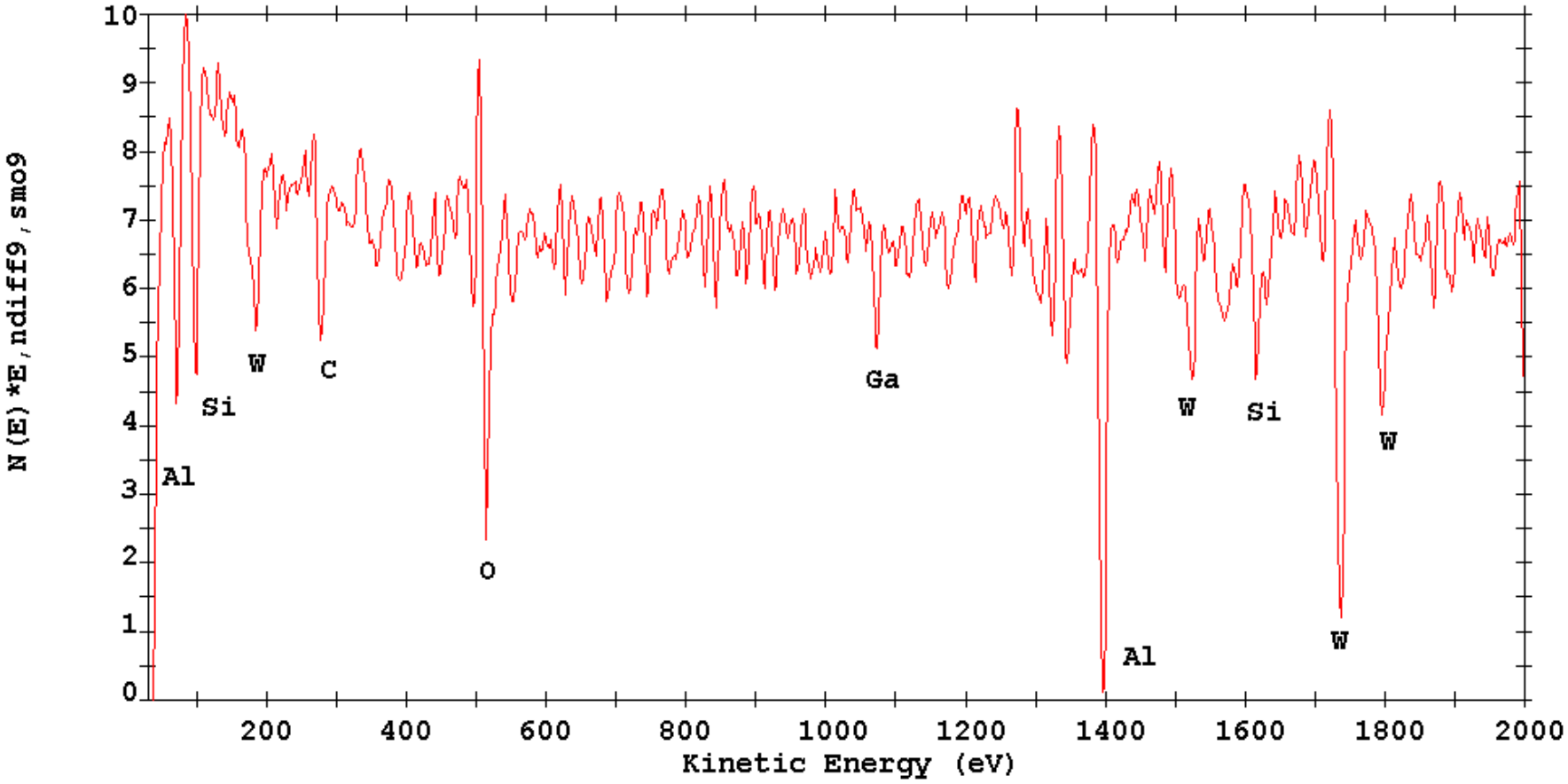


FIBed Bond Pad

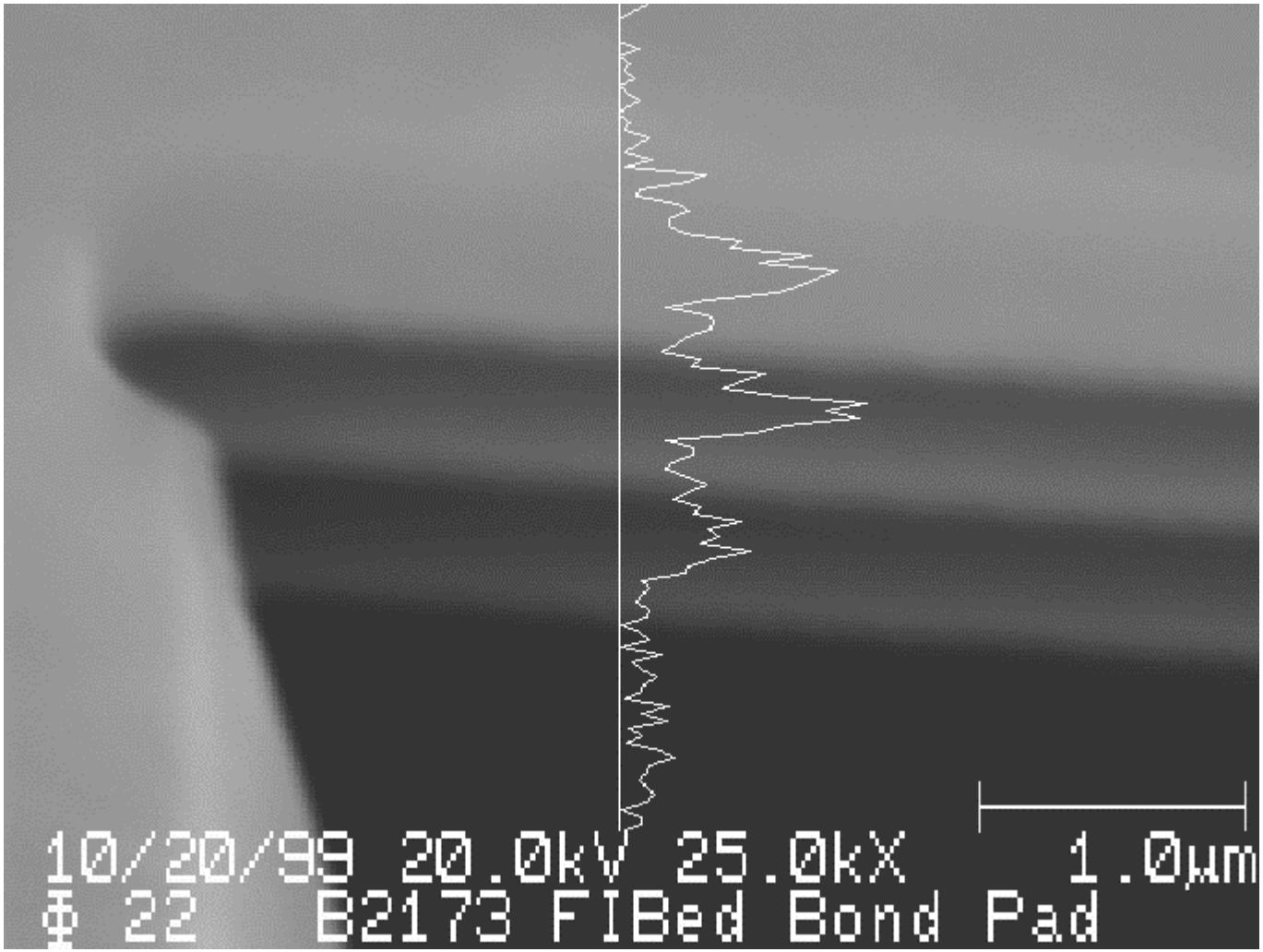
AES Survey PC 20 Oct 99 Area: 1 Acq Time: 3.29 min

File: b2173021 FIBed bond pad As received

Scale: 23.411 kc/s Offset: -149.310 kc/s Ep: 20.00 kV Ip: 8.994e-09A



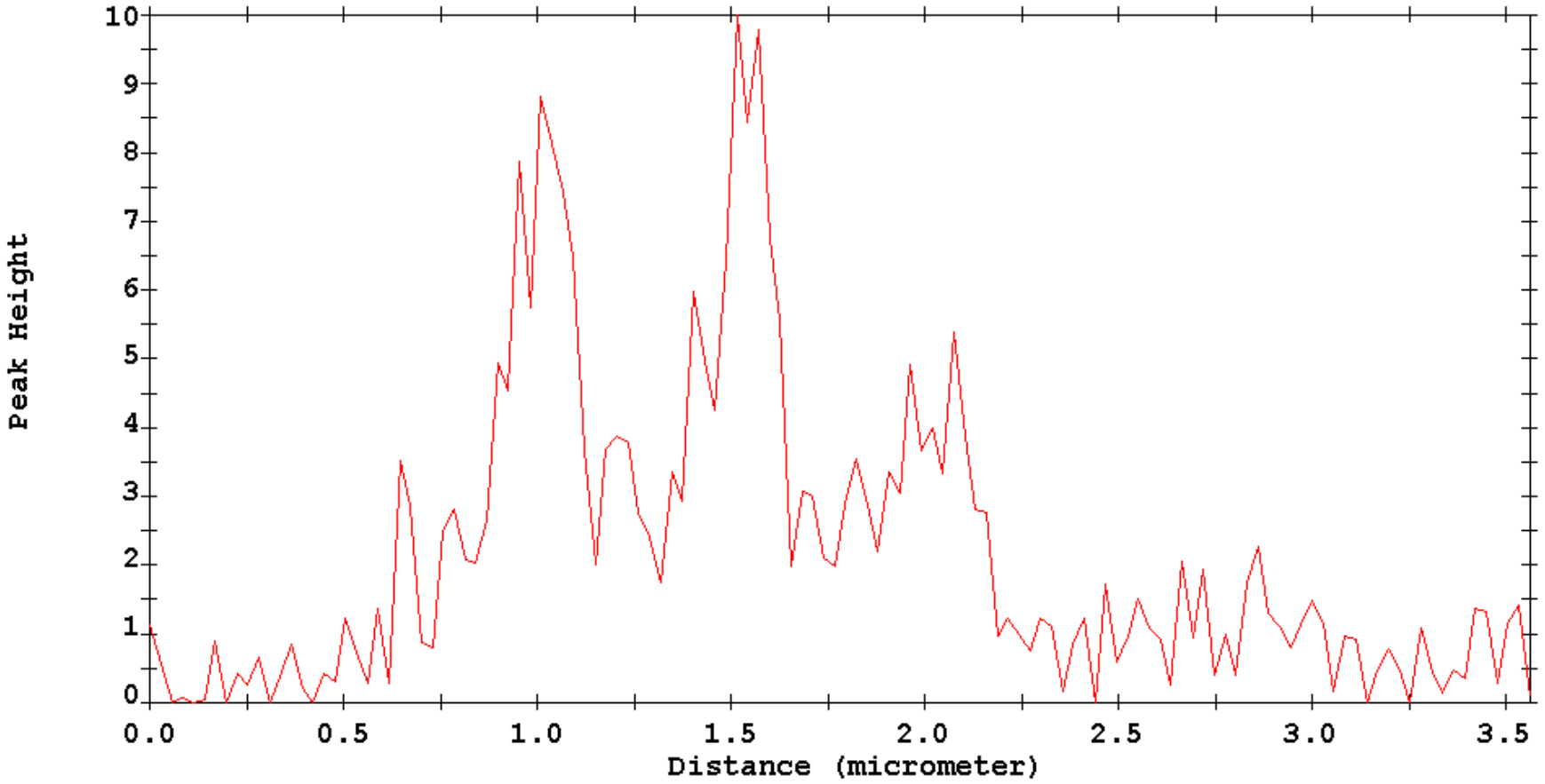
FIBed Bond Pad W line



AES Line PC 20 Oct 99 Region: 1(W2) Line: 1 Acq Time: 0.85 min

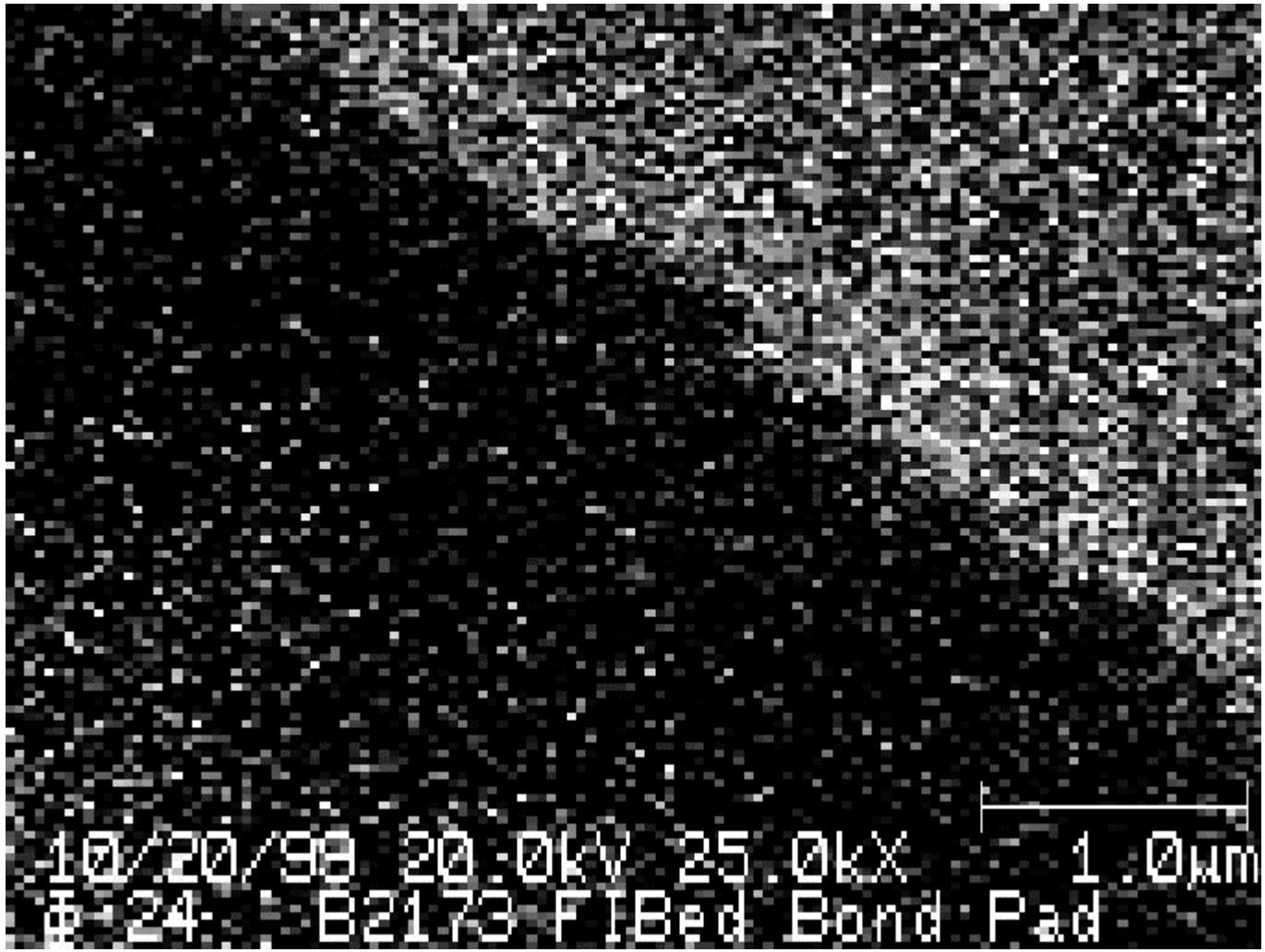
File: b2173022 FIBed bond pad As received

Scale: 1.742 kc/s Offset: 0.000 kc/s Ep: 20.00 kV Ip: 8.994e-09A

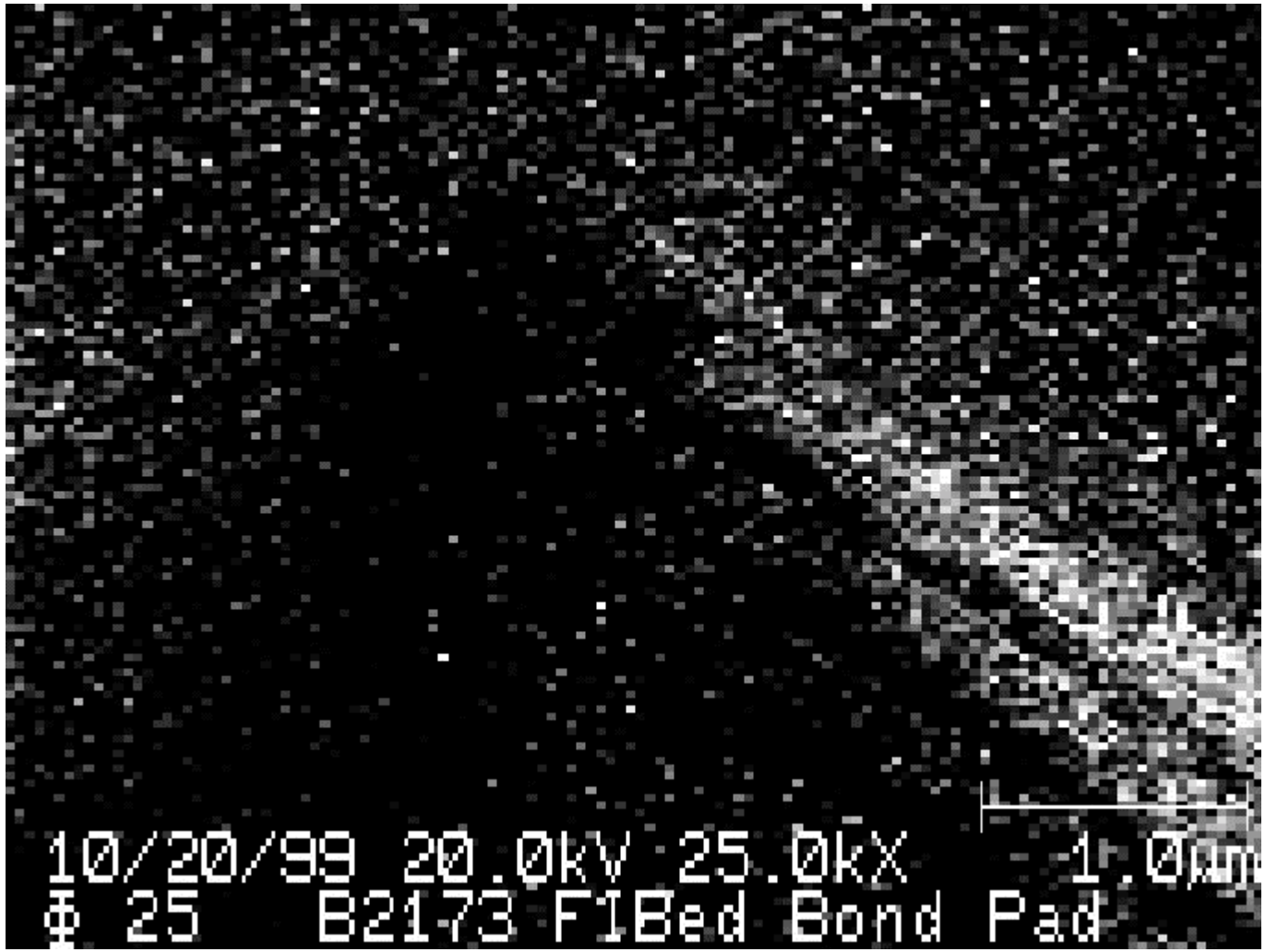


FIBed Bond Pad W image

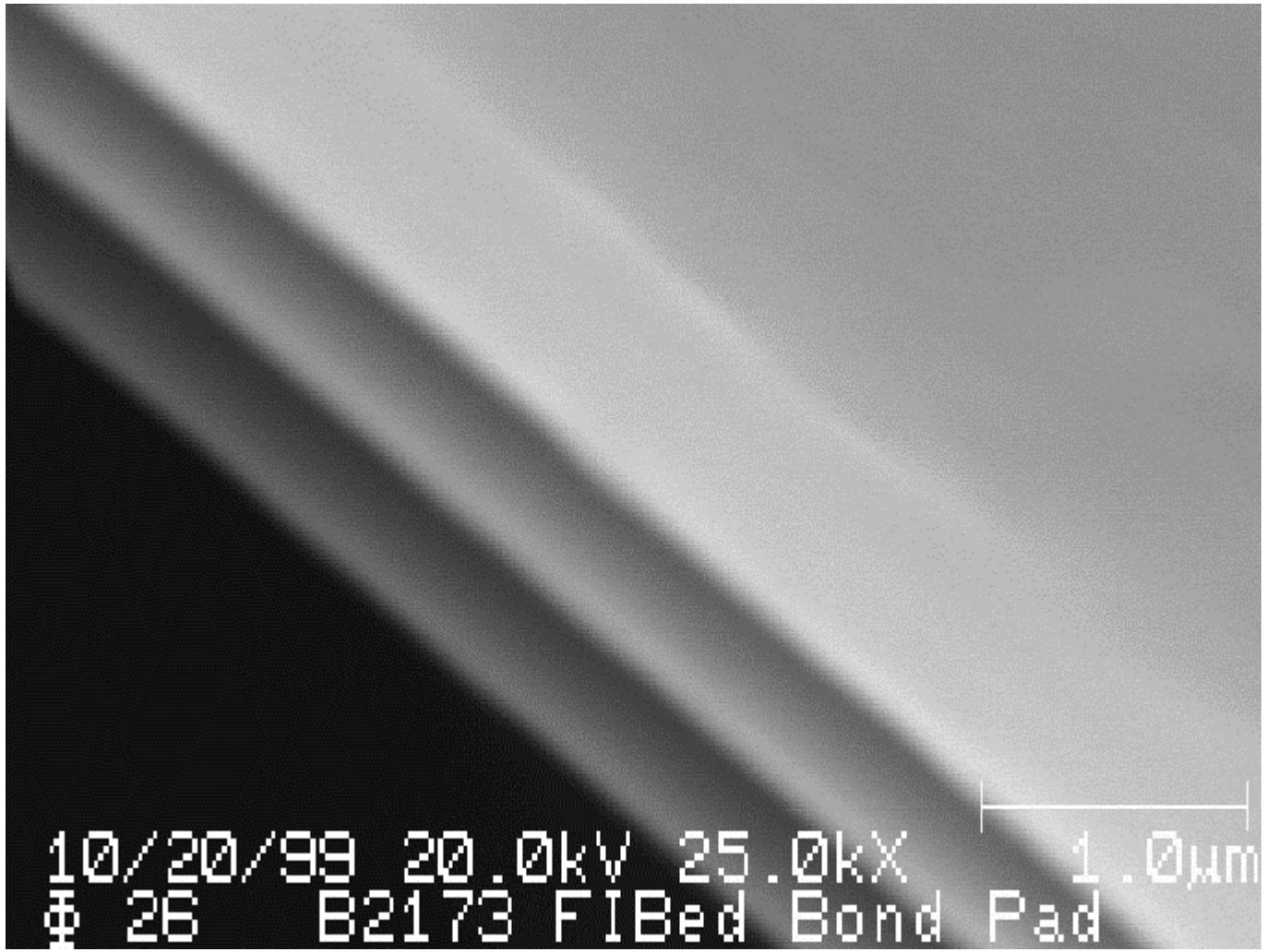
FIBed Bond Pad C image



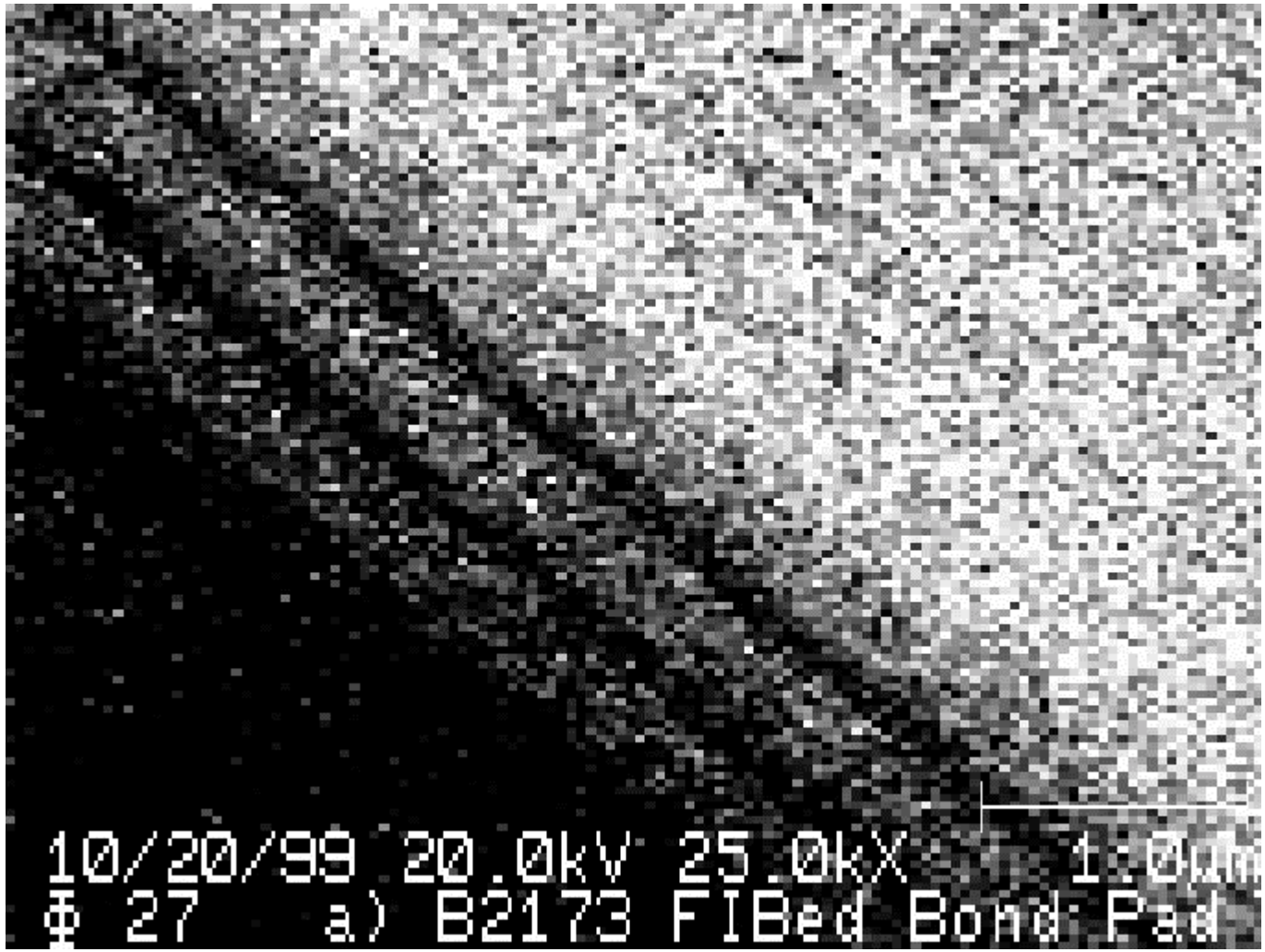
FIBed Bond Pad Al image



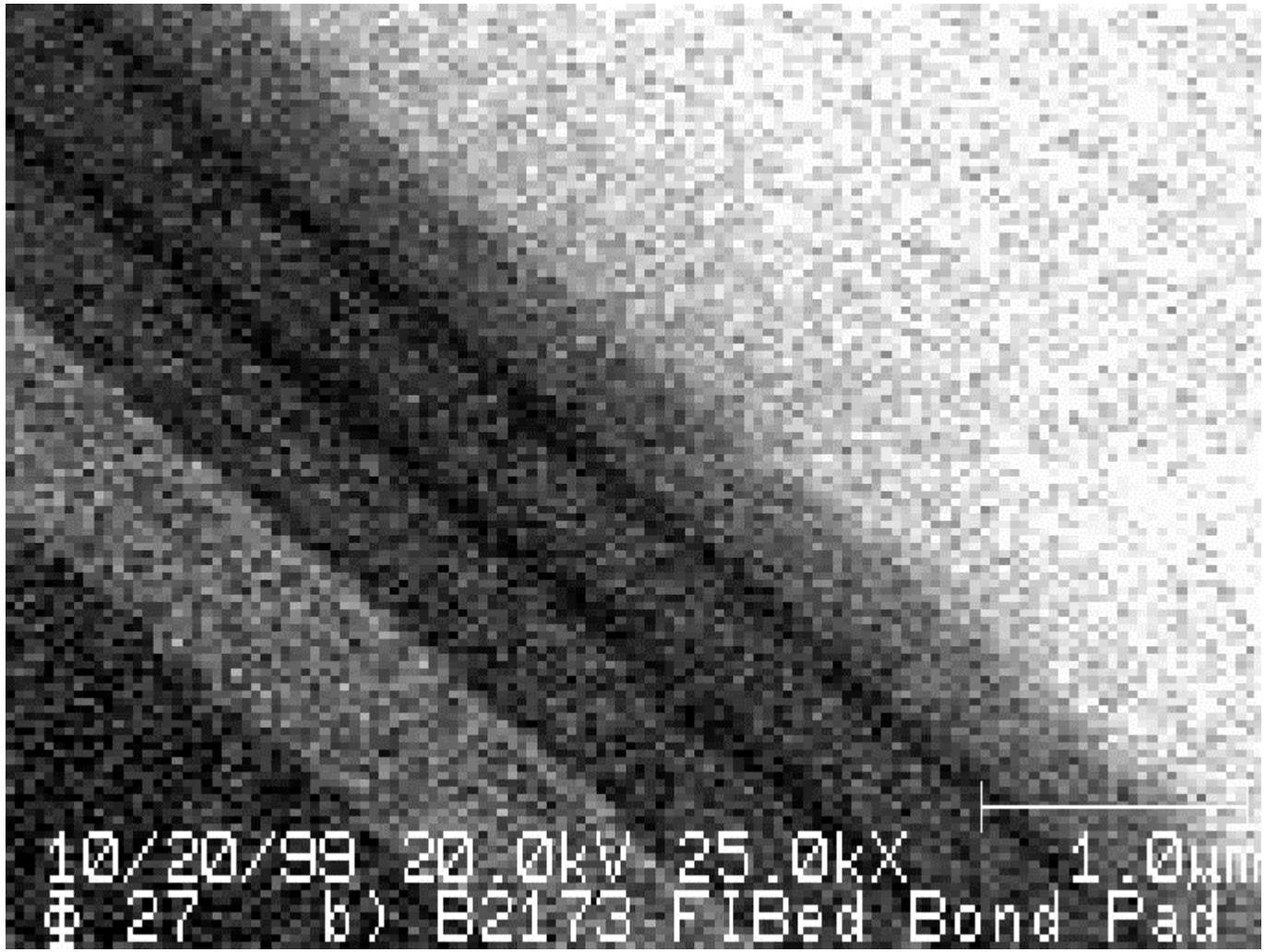
FIBed Bond Pad



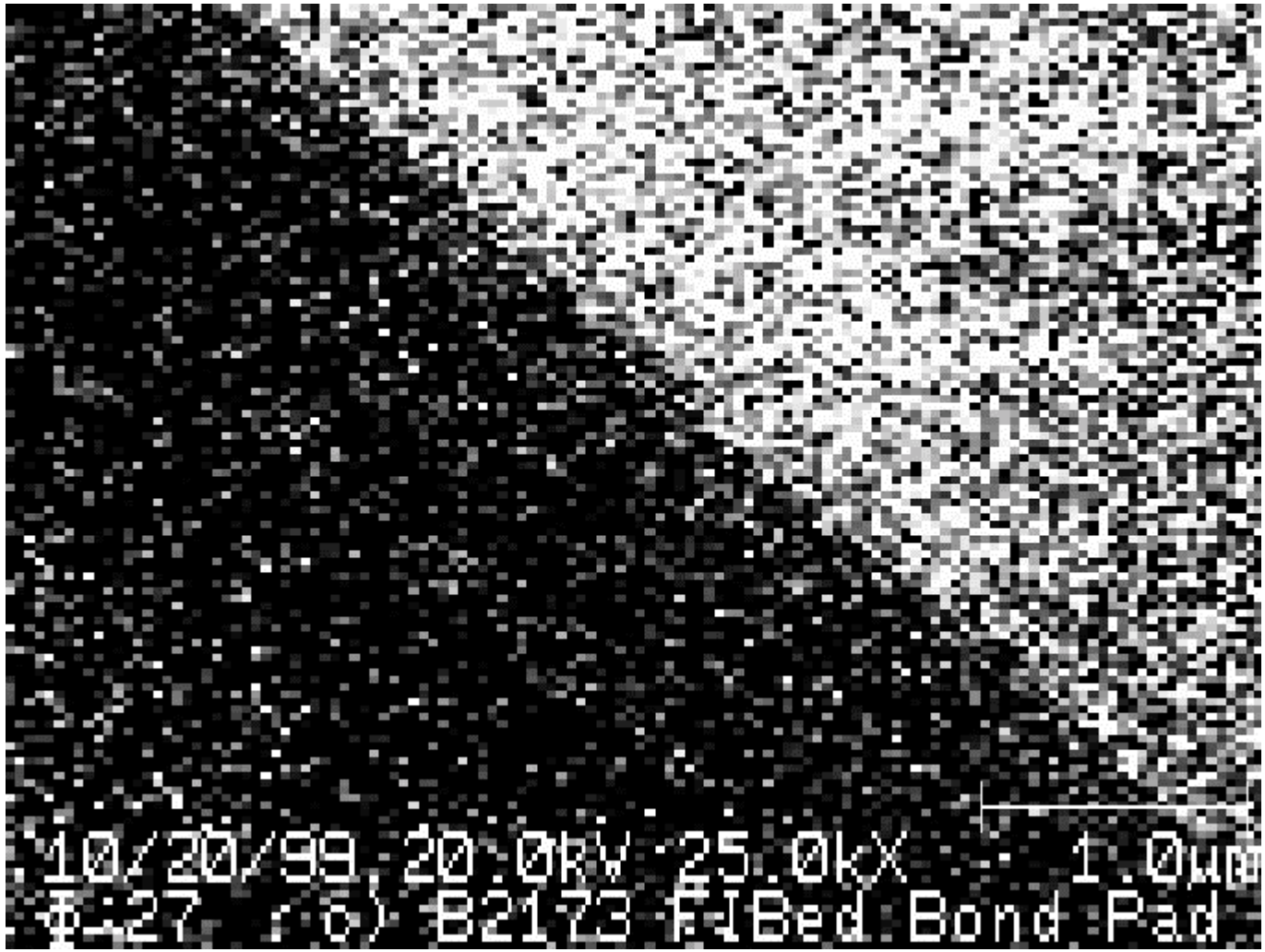
FIBed Bond Pad Al image



FIBed Bond Pad O image

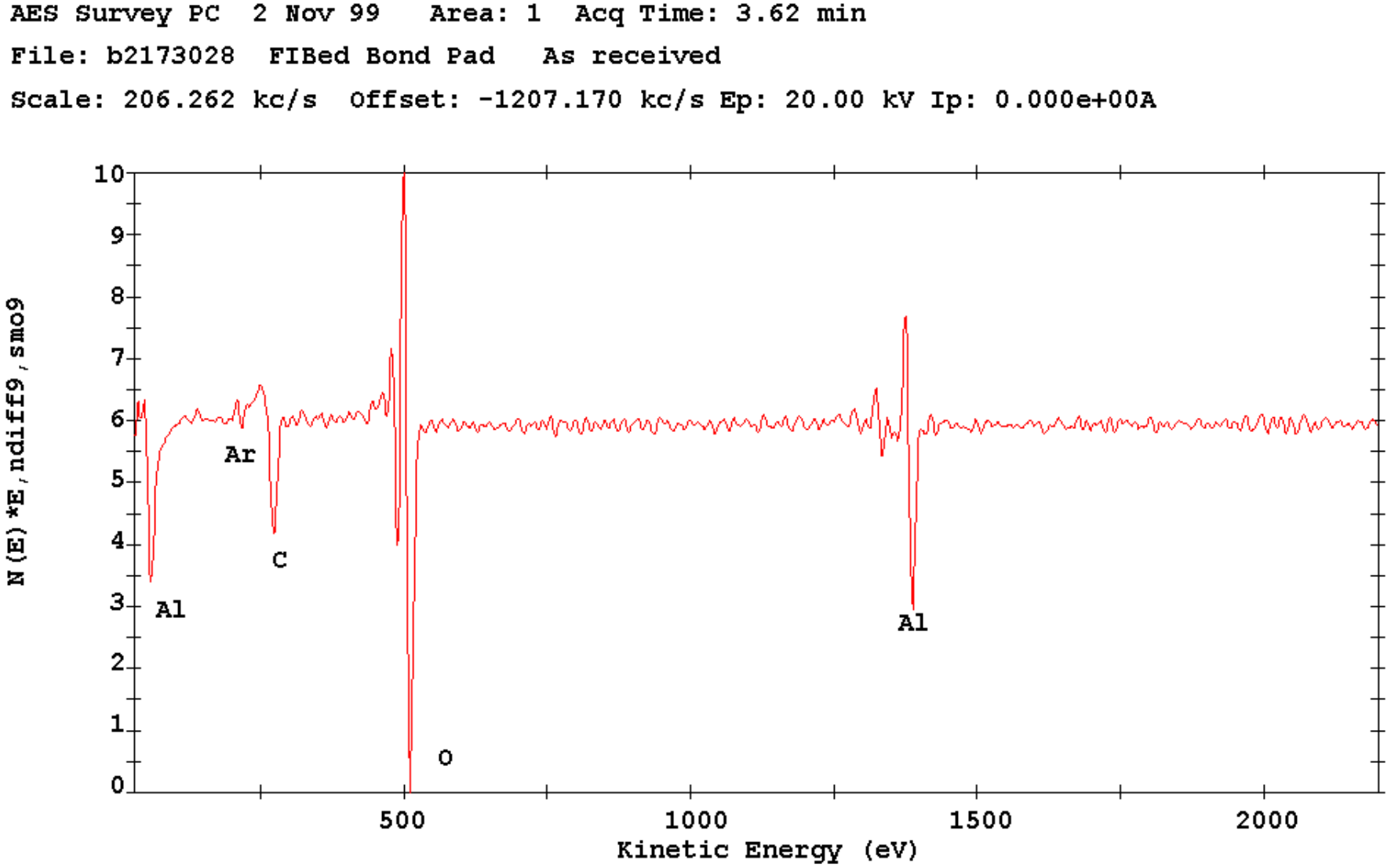


FIBed Bond Pad C image

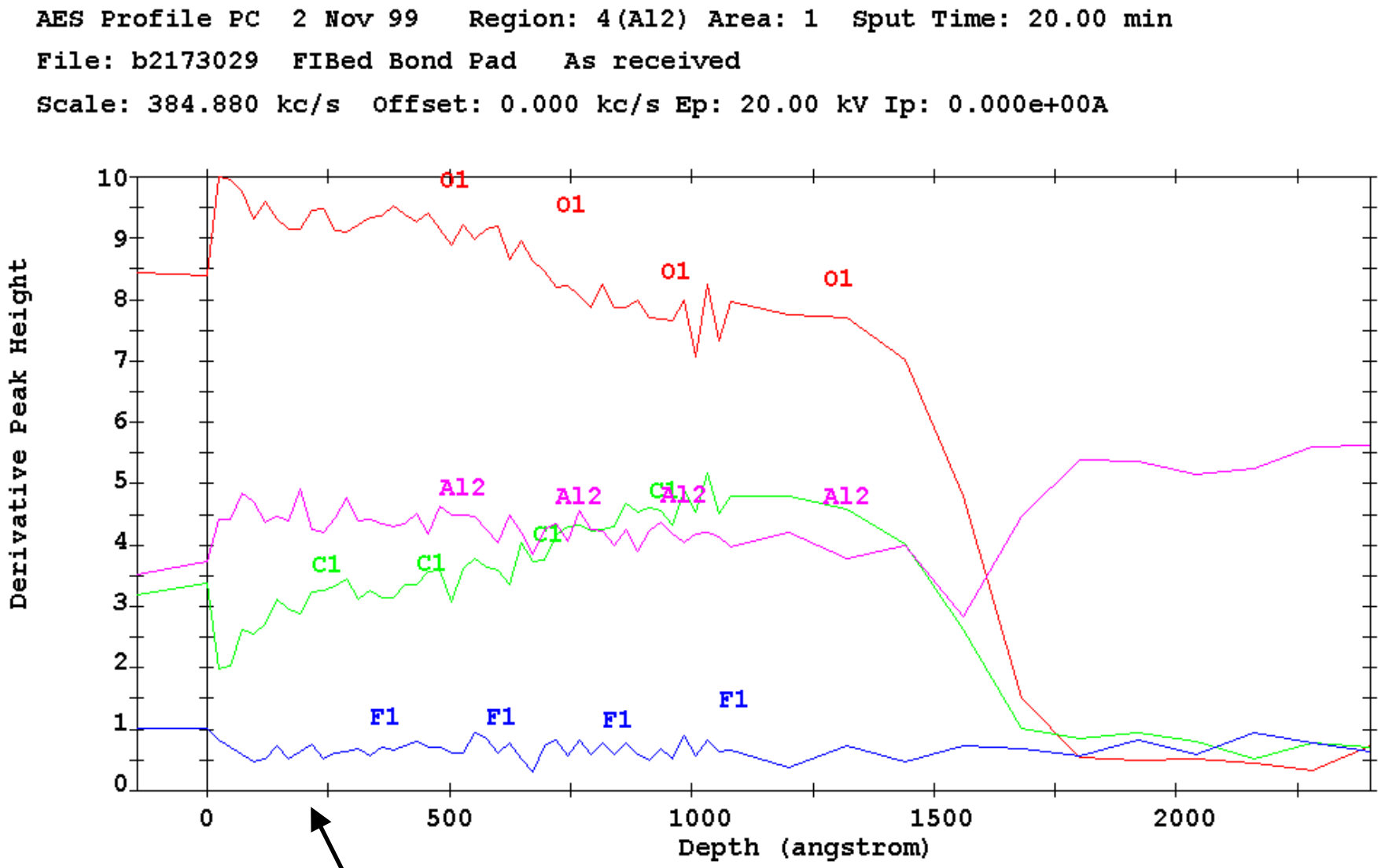


Comments on FIB and Auger Line Analyses

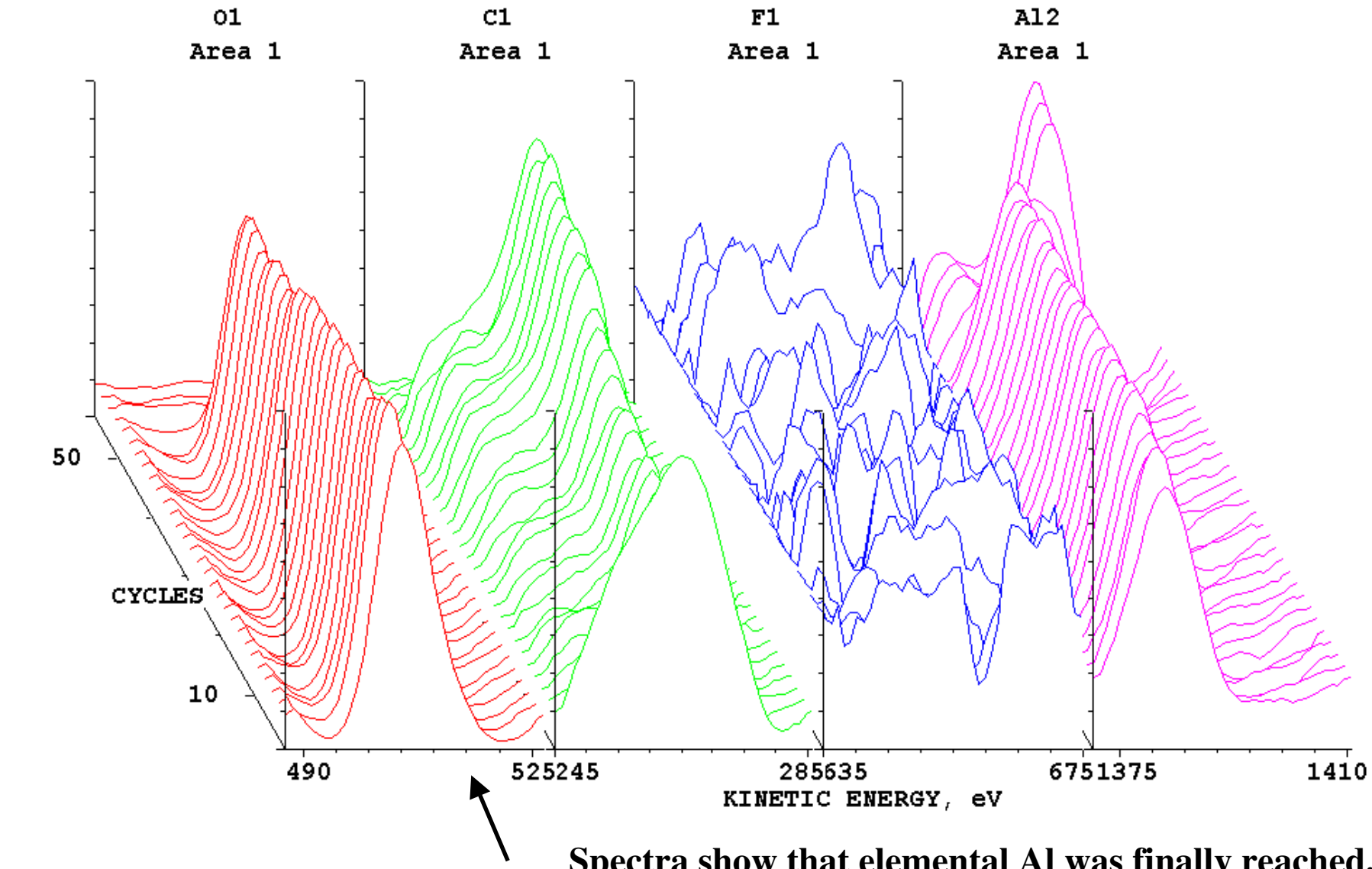
- Can clearly see three Al layers present in HP bond-pad, W via material and oxide between layers.
- Carbon/Oxide layer is on top of the upper Al layer, and it is quite thick. It is essentially impossible with this analysis to see the "corner" of this layer and hence measure its thickness (there is no distinguishing feature between the body of the layer and the surface of the layer).
- In the end, the line analyses were quite inconclusive.
- As a final step, another area analysis was done, increasing the sputter cycle step size still further, and extending the depth of the scan.



Perform a final area scan to look for end of contamination layer. Initial survey shown here.



Depth profile shows the end of the C and O contamination. There is no sign of the native oxide (with tell-tale F signal), but step size was very large.

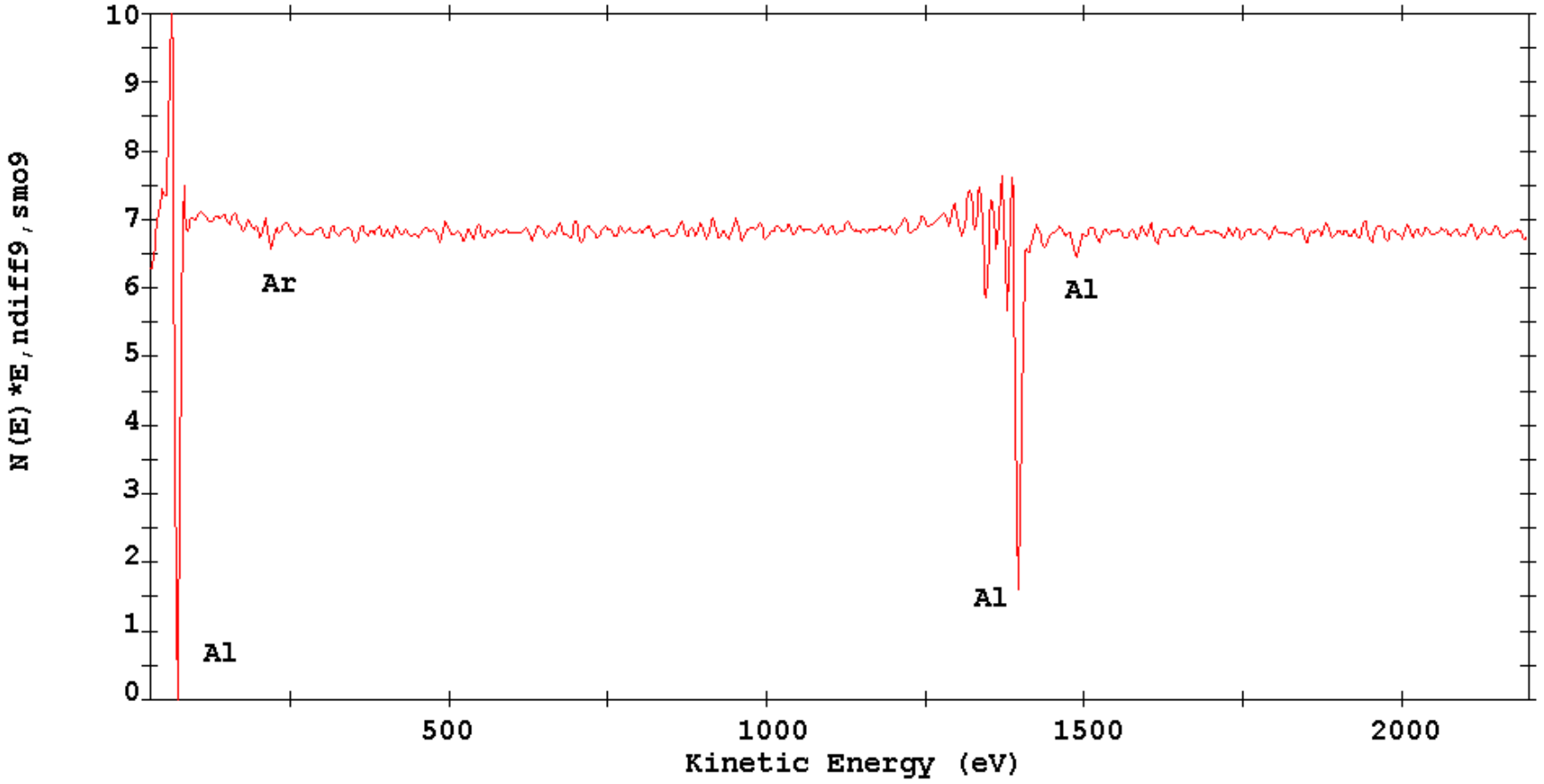


Spectra show that elemental Al was finally reached.

AES Survey PC 2 Nov 99 Area: 1 Acq Time: 3.62 min

File: b2173030 FIBed Bond Pad After profile

Scale: 218.234 kc/s Offset: -1471.680 kc/s Ep: 20.00 kV Ip: 0.000e+00A



Conclusions

- No contamination is seen on the pads prior to bump-deposition.
- Significant organic contamination is present after both the bump-deposition step and the final flip-chip step (there seems to be no obvious difference between the two). The thickness of the contamination layer is difficult to measure because its sputter rate is probably lower than SiO2. The expert quoted a range of 600-1500A, based on his experience with sputter rates.
- The Auger technique does not allow any more detailed analysis of what this contamination is. It is mixed in with Al-oxide, suggesting that the organic contamination is present on the pad, and gets mixed in with Al-oxide during a high-temperature step, but this is speculation.
- The expert was rather astonished that we could bond at all to pads with this level of contamination. Certainly reliability and pull-strength will not be normal under these conditions. Hopefully, after better understanding of the IZM processing steps, modifications to the processing can be made to eliminate this contamination.